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REPLACEMENT OF ACTIVATED SLUDGE SECONDARY CLARIFIERS BY DYNAMIC STRAINING

Michael Joyce, et al

FMC Corporation

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REPLACEMENT OF ACTIVATED SLUDGE SECONDARY CLARIFIERS BY DYNAMIC STRAINING

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16. ABSTRACT

Pilot plant studies were conducted on domestic wastewater to determine the feasibility of replacing conventional activated sludge gravitational clarifiers by dynamic straining. The dynamic strainers consisted of a rotating cylinder cleaned by an internal ultrasonic transducer. A primary strainer was placed and operated directly in the mixed liquor in the aeration tank. A secondary strainer was installed and operated in a separate tank to further clarify the effluent from the primary strainer.

This work indicated that dynamic straining is a technically feasible process for replacing conventional activated sludge gravitational clarifiers. Suspended solids removals of well over 99 percent were achieved with a single primary strainer operating in the pilot plant aerator with a mixed liquor suspended solids concentration of over 6,500 mg/l. When operated at lower specific flow rates, primary straining appears to be capable of consistently producing an effluent suspended solids in the 15-30 mg/l range.

Present economic predictions indicate that plants equipped with primary and secondary dynamic strainers would cost more than plants utilizing conventional secondary gravity clarifiers. This factor can be tempered by several projected dynamic straining advantages. Two-stage dynamic straining has excellent application where space limitations exist. Secondary gravity clarifiers could be eliminated under the right conditions and aeration tank sizes could be appreciably smaller with the higher MLVSS concentrations achievable with dynamic straining. An existing overloaded activated sludge plant could be upgraded with primary straining only without expanding the facilities. In locations or applications where filamentous growth is prevalent, primary straining could be used to effectively control bulking. During the testing program, dynamic straining revealed itself to be resistant to shock loading.

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REPLACEMENT OF ACTIVATED SLUDGE SECONDARY CLARIFIERS BY DYNAMIC STRAINING

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REVIEW NOTICE

The National Environmental Research Center-Cincinnati has reviewed this report and approved its publication. Approval does not signify that the contents necessarily reflect the views and policies of the U. S. Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

FOREWORD

Man and his environment must be protected from the adverse effects of pesticides, radiation, noise, and other forms of pollution, and the unwise management of solid waste. Efforts to protect the environment require a focus that recognizes the interplay between the components of our physical environment--air, water, and land. The National Environmental Research Centers provide this multidisciplinary focus through programs engaged in

- studies on the effects of environmental contaminants on man and the biosphere, and
- a search for ways to prevent contamination and to recycle valuable resources.

As part of these activities, the study described herein presents a pilot-scale evaluation of the feasibility of replacing conventional secondary gravity clarifiers in the activated sludge process with dynamic strainers equipped with ultrasonic transducers.

A. W. Breidenbach, Ph.D.
Director
National Environmental
Research Center, Cincinnati

ABSTRACT

Pilot plant studies were conducted on domestic wastewater to determine the feasibility of replacing conventional activated sludge gravitational clarifiers by dynamic straining. The dynamic strainers consisted of a rotating cylinder cleaned by an internal ultrasonic transducer. A primary strainer was placed and operated directly in the mixed liquor in the aeration tank. A secondary strainer was installed and operated in a separate tank to further clarify the effluent from the primary strainer.

This work indicated that dynamic straining is a technically feasible process for replacing conventional activated sludge gravitational clarifiers. Suspended solids removals of well over 99 percent were achieved with a single primary strainer operating in the pilot plant aerator with a mixed liquor suspended solids concentration of over 6,500 mg/l. When operated at lower specific flow rates, primary straining appears to be capable of consistently producing an effluent suspended solids in the 15-30 mg/l range.

Present economic predictions indicate that plants equipped with primary and secondary dynamic strainers would cost more than plants utilizing conventional secondary gravity clarifiers. This factor can be tempered by several projected dynamic straining advantages. Two-stage dynamic straining has excellent application where space limitations exist. Secondary gravity clarifiers could be eliminated under the right conditions and aeration tank sizes could be appreciably smaller with the higher MLVSS concentrations achievable with dynamic straining. An existing overloaded activated sludge plant could be upgraded with primary straining only without expanding the facilities. In locations or applications where filamentous growth is prevalent, primary straining could be used to effectively control bulking. During the testing program, dynamic straining revealed itself to be resistant to shock loading.

This report was submitted in fulfillment of Contract No. 68-03-0102, by the FMC Corporation, Environmental Engineering Laboratories, under the sponsorship of the U. S. Environmental Protection Agency.

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SECTION I

CONCLUSIONS

Dynamic straining, wherein solids are removed by a rotating drum utilizing a stainless steel micro-mesh fabric, cleaned by ultrasonics and the rotational effect, is a technically feasible process for replacement of conventional activated sludge gravitational clarifiers. Suspended solids removals of well over 99 percent can be achieved with primary strainers operating in mixed liquor with a suspended solids concentration of over 6,500 mg/l. When operated at lower specific flow rates of 1.35-2.70 l/sec/m^2 (2-4 gpm/ft^2), primary straining appears capable of consistently producing an effluent which equals or betters the Federal Secondary Treatment Standards for suspended solids of 30 mg/l or 85 percent overall plant removal, whichever results in the lowest residual.

Further improvement in suspended solids removal is effected by using a secondary strainer in series with the primary strainer. Suspended solids removed during secondary straining are returned to the mixed liquor aeration system.

Commercially acceptable specific flow rates of up to 8 l/sec/m^2 of filtering surface (12 gpm/ft^2) have been demonstrated at a mixed liquor suspended solids (MLSS) concentration of 6,500 mg/l. Specific flow rates approximately twice those stated above can be achieved at the lower suspended solids operation for the secondary strainer.

A 10-micron nominal rating stainless steel Robusta weave is the recommended cloth for both the primary and secondary strainers. Cloths with smaller nominal openings inhibit flow rate without any significant reduction in effluent suspended solids. Cloths with larger openings do not exhibit sufficiently higher specific flow rates to warrant the decrease in effluent quality.

Specific flow rate performance is affected by nominal opening size of the fabric, suspended solids concentration, rotational speed, and hydraulic head. Suspended solids removals are affected by nominal pore size, concentration of suspended solids in the liquid surrounding the strainer, and the peripheral speed of the strainer. In general, maximum specific flow rates occurred at net hydraulic heads of 25 to 75 mm (1 to 3 in) over the range of interrelated variables studied during this pilot plant program. Solids removal efficiencies decrease and specific flow rates increase rapidly as the rotational speed of the drum is increased.

A predominantly filamentous biomass, which was encouraged to proliferate throughout the experimental program, appears to be the most desirable mixed liquor culture for the application of dynamic straining, combining the attributes of high specific flow rates and suspended solids removals.

Preliminary economic comparisons for plants with conventional gravitational clarification and plants with two-stage dynamic straining clarification with capacities of 3,785 and 37,850 m^3/day (1 and 10 mgd) indicate that dynamic straining plants would have a total construction cost approximately 8.2 percent higher than conventional plants at the 3,785 m^3/day (1 mgd) level, and approximately 21.5 percent higher at the 37,850 m^3/day (10 mgd) level. These estimates were based on the current FMC standard strainer production model. From a process applications standpoint, this basic model was sized for relatively low solids concentrations such as found in wastewater treatment lagoons. No effort was made to redesign equipment to optimize costs for high solids concentrations which would prevail in mixed liquor applications.

Annual operating costs for dynamic straining are also indicated to be higher than those for conventional operations, substantially so at the higher plant capacity of 37,850 m^3/day (10 mgd). However, these operating cost estimates were based on very preliminary conservative assumptions concerning labor, maintenance, and power requirements for the strainers. Amortization has a significant effect because of the differences in total construction costs.

The economics of dynamic straining can be significantly improved by replacing the secondary strainer with a sand filter or gravitational clarifier operating at high overflow rates. It was indicated during this study that simple gravitational clarification of the fine colloidal solids in the primary strainer effluent would be difficult, suggesting that chemical addition may be necessary to obtain satisfactory coagulation and flocculation.

Upgrading of existing organically and/or hydraulically overloaded treatment plants appears to be a viable application for primary straining. Higher MLSS levels could be maintained (provided the necessary additional oxygen transfer capability existed or could be acquired) while concomitantly decreasing solids loadings on existing secondary clarifiers to very low levels. A significant improvement in both biological and secondary clarifier performance would be expected by such a modification of operating conditions. This could be accomplished with little, if any, increase in land requirements for the treatment plant.

Many activated sludge treatment plants experience prolonged periods of uncontrolled bulking due to filamentous growth. Installation of a primary strainer directly in the mixed liquor would eliminate the adverse effects of bulking on secondary clarifier operation and on effluent quality.

SECTION II

RECOMMENDATIONS

Although day-to-day strainer operating and performance data were taken and independent characterization data for the important operating variables of the strainer were confirmed and appeared reproducible, additional work is recommended to evaluate the steady-state performance of the strainer and the response to diurnal flow variations. This is especially important to establish methodology for automatic control of strainer peripheral speed under varying flow conditions.

Suspended solids concentrations in the primary strainer effluent were low enough to warrant testing of granular-media filtration to provide a polished final effluent without use of the relatively expensive secondary strainer. Improvement of effluent quality, reduction of costs, and reduction of return flow to the aeration tank are indicated by such a substitution.

The nature of the biological solids was shown to be a very important consideration in the performance of the strainer. Further work should be undertaken to establish primary strainer performance with different activated sludge biomass characteristics. For instance, comparison of performance on a nitrifying sludge versus the predominantly heterotrophic sludge grown under the highly loaded carbon removal conditions used for this study would provide valuable design information. Microscopic studies and evaluation of performance with respect to different load factors, cell retention times, and other biological processing parameters would aid in defining the range of feasible strainer applications.

The very cursory work performed on this project on settleability of the fine solids contained in the primary strainer effluent should be expanded and coagulation and flocculation of these solids studied using conventional chemical techniques. This would be of importance in determining design data for utilization of the primary strainer in conjunction with an existing overloaded secondary clarifier. Also, coagulation and flocculation of these solids should prove beneficial to the performance of a secondary strainer, if applied, in the production of a more polished effluent and the minimization of return flows.

When operated at lower specific flow rates of 1.3 to 2.6 $l/sec/m^2$ (2 to 4 gpm/ft^2), preliminary results indicated that a primary strainer

was capable of producing an effluent that without further clarification, filtration, or straining would meet the Federal Secondary Treatment Standards for suspended solids, i.e.less than or equal to 30 mg/l. With sufficient standby strainers and with a 100 percent reliable back-up power supply source, this raises the possibility of completely eliminating secondary clarifiers and downstream polishing devices in certain situations. This potential application of primary straining should be more thoroughly evaluated via a series of longer-term pilot runs.

Another potential application of primary straining which merits evaluation is as an independent first-stage clarification device in a two-stage activated sludge system. This type of system is used where year-round nitrification is required. The optimum residual BOD_5 and suspended solids concentrations in the first-stage effluent are 35-50 mg/l each. Bleed through of these two constituents in these amounts enhances flocculation and settling of the second-stage nitrifying sludge. It appears primary strainers installed in the first-stage reactor could readily be tailored to produce the optimum desired first-stage effluent quality.

One variable not studied in the program reported herein was the power supply to the sonic transducer. In concurrent studies with FMC field units, this variable has had an appreciable effect on attainable specific flow rates and suspended solids removal efficiencies in low suspended solids applications. The impact of this variable in high suspended solids mixed liquor applications should be investigated.

SECTION III

INTRODUCTION

The treatment capacity of an activated sludge plant is most often limited by the secondary clarifier. As the volumetric BOD loading increases, the MLSS concentration under aeration must be gradually increased to maintain the organic (F/M) loading within the desired operating range. However, an increase in MLSS concentration leads to a proportional increase in mass (solids) loading on the secondary clarifier. At some point, the solids loading on the secondary clarifier will begin to exceed the sludge thickening capability of that unit, necessitating a reduction in MLSS level and resulting in a higher than desired F/M loading. This in turn may result in decreased soluble organics removals and poor biomass settling characteristics. Poor sludge settling characteristics can also result from a predominantly filamentous sludge, even though this type of sludge yields efficient BOD removal.

The problems mentioned above suggest that a better method of liquid/solids separation would result in greater treatment plant capacity and reliability. Straining is a method of liquid/solids separation which is not dependent on the settleability of the solids involved. This contract was concerned with the investigation of separating activated sludge solids using the process of straining as an alternative to gravitational settling.

An experimental study was undertaken to evaluate the technical performance of dynamic straining. Using the data obtained, a preliminary economic evaluation has been completed comparing secondary clarifiers and dynamic strainers. The dynamic strainers consist of rotating drums covered with micro-mesh fabric. The fabric is cleaned by ultrasonic energy and the rotational effect.

FMC Corporation has been investigating the process of straining for about five years. The dynamic strainer itself has been used for several different applications. For low suspended solids conditions, it was tested on municipal treatment plant and aerated lagoon effluents. This strainer has also been used to strain the mixed liquor resulting from the treatment of cheese whey.

As an offshoot from this previous work, the dynamic strainer was then evaluated on domestic wastewater generated mixed liquor in a package plant at the Environmental Engineering Laboratories in Santa Clara, California. The results of this limited experiment indicated that the strainer could remove at least 90 percent of the MLSS at a specific flow rate of 4.8 l/sec/m^2 (7 gpm/ft^2). This work along with the operational problems of secondary clarifiers led to the proposal of this project.

The project was broken down into three phases; Phase I - equipment manufacture, Phase II - equipment installation and process shakedown, and Phase III - pilot plant operation and evaluation. The entire project was scheduled for completion over a 9 to 10 month period.

The dynamic strainers were designed and constructed during the first phase. The design was completed at the FMC Environmental Engineering Laboratories, and the strainers were fabricated at the FMC Central Engineering Laboratories. The package plant used in this study was already in place at Environmental Engineering Laboratories.

During the second phase, the primary strainer was mounted in the aeration tank. The secondary strainer was placed in another smaller auxiliary tank. The remainder of the shakedown phase consisted of building solids in the aeration tank, installing the composite samplers, and adjusting the hydraulics of the system.

The third phase consisted of two different methods of evaluating the strainers. The system was operated continuously with daily monitoring and sample collection. Also, specific tests were performed during this period to determine specific flow rates and suspended solids removals for several different sets of operating conditions.

SECTION IV

DESCRIPTION OF EQUIPMENT

Each dynamic strainer unit consists basically of five parts as shown in Figure 1; the supporting drum basket, the micro-mesh fabric, the ultrasonic cleaning transducer, the drive unit, and the outer protective expanded metal cover. Sketches of the primary and secondary dynamic strainer installations utilized on this project are shown, respectively, in Figures 2 and 3. Photographs of the strainer installations are presented in Figure 4.

The 0.61-m (2-ft) diameter by 0.61-m (2-ft) high inner expanded metal drum basket supports the strainer fabric while allowing the liquid to pass through to the inside. The micro-mesh strainer fabric is wrapped around the periphery of the basket and sealed against leaks by a silicone rubber based adhesive. Only stainless steel fabric was used in this study. The specifications of the four cloths that were tested are listed in Table 1, Kressilk Products, Incorporated, (1).

The ultrasonic transducer is located inside the basket and mounted on the stationary axle. The power for this unit is supplied by an ultrasonic generator located remotely in a control cabinet.

The ultrasonic transducer is exposed to the full vertical length of the cloth. The ultrasonic energy excites the fabric and sheds the solids back into the liquid reservoir. The complete cloth is cleaned each revolution as the basket rotates past the stationary transducer. This cleansing method is very simple, economical, and reliable. Also, it should be noted that conventional microscreen spray cleaning systems are not nearly as efficient at the high MLSS concentrations of interest in this project.

The basket and strainer fabric are rotated by a 3-hp electric motor attached to a variable speed drive unit. This unit provides a maximum rpm of 180 and a minimum rpm of 30. The rotational effect of the strainer also helps to keep the fabric free of solids buildup.

The strainer units are supported by brackets made of angle iron mounted on the top of the tanks. The strainer itself and the effluent piping are connected with the use of a WECO Air-O-Union seal. This allows the strainer to be lowered through the liquid and connected without draining the tank. Then the seal is inflated to 60-80 psig to secure the strainer outlet pipe. The wastewater flow coming in through the fabric discharges through the outlet pipe to a standpipe outside the tank. The standpipe maintains an adequate water level in the strainer to keep the ultrasonic unit submerged so that it can clean the fabric effectively.

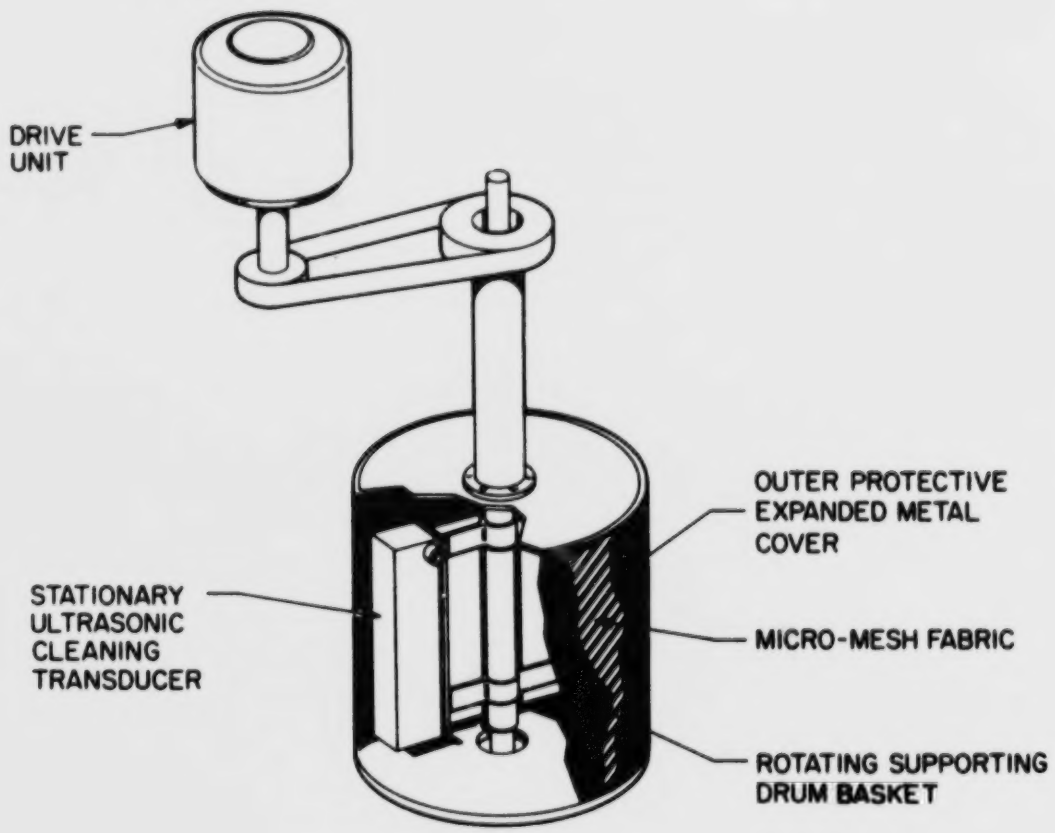


FIGURE 1

DYNAMIC STRAINER UNIT

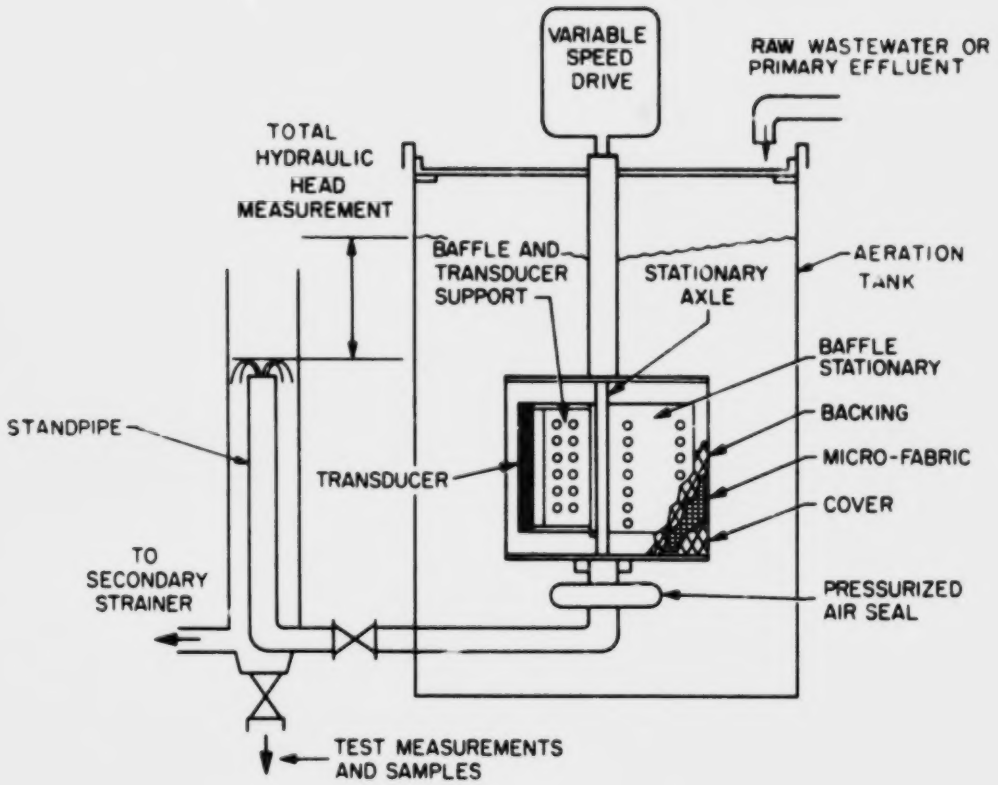


FIGURE 2

PRIMARY STRAINER

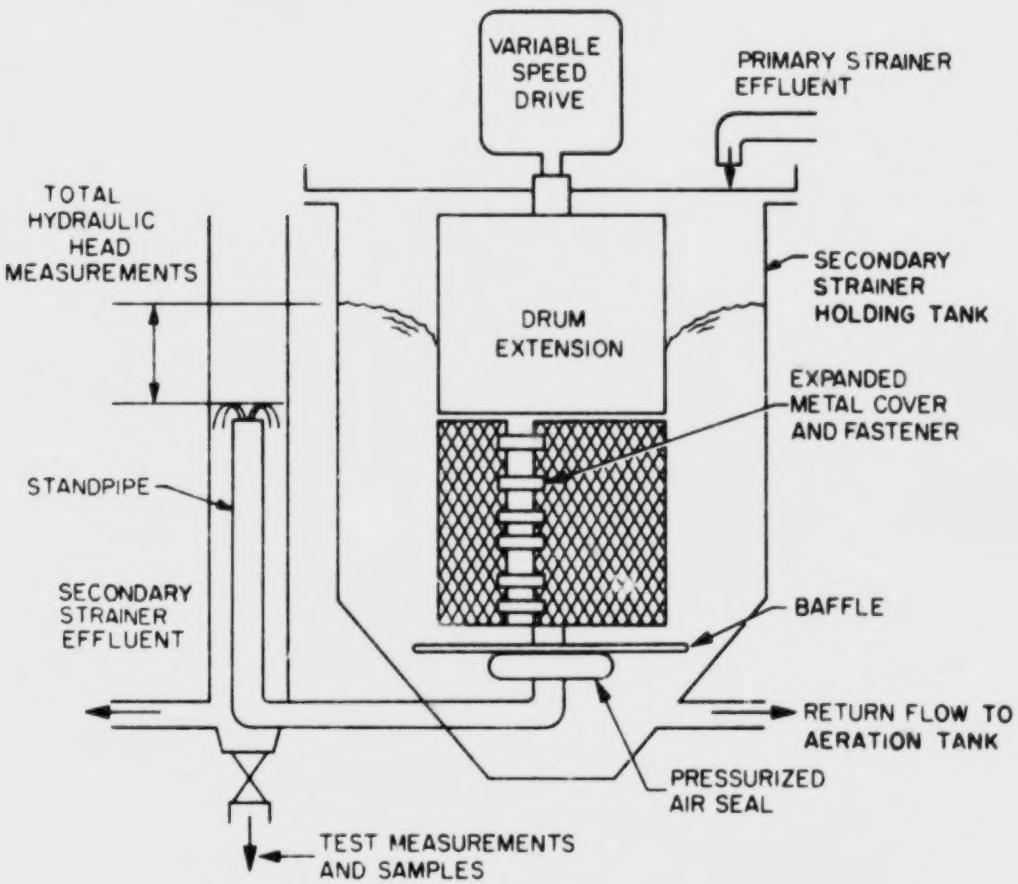
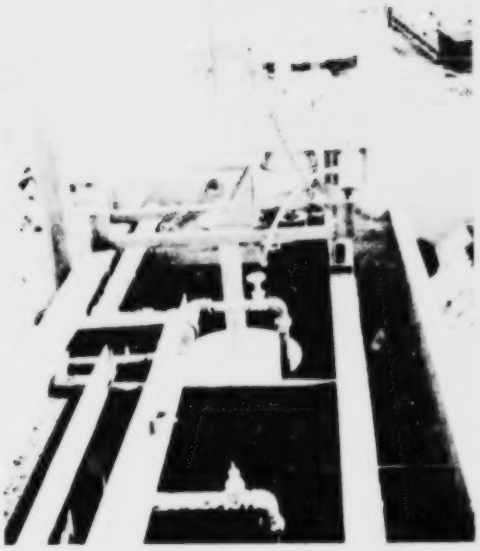
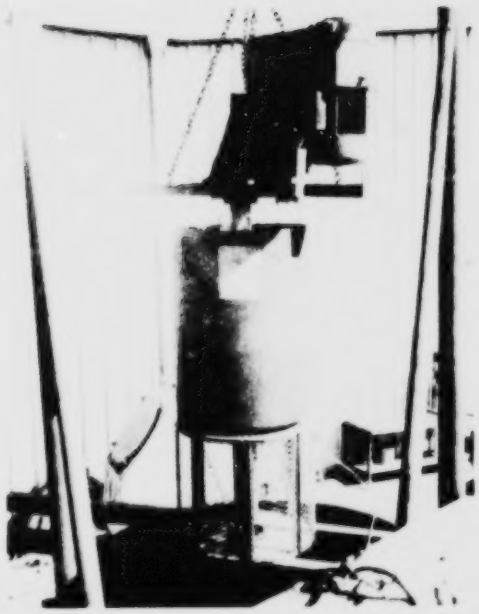


FIGURE 3

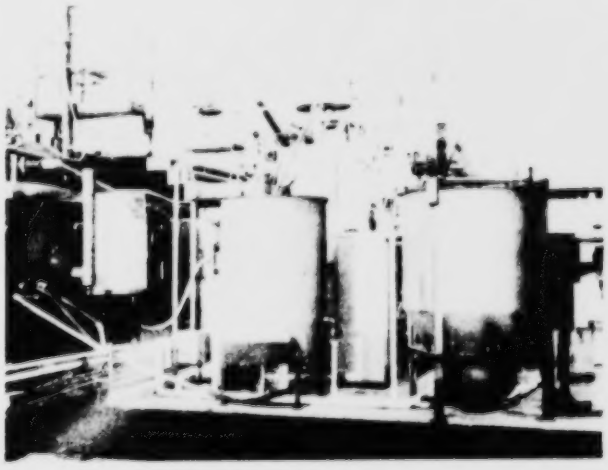
SECONDARY STRAINER



Primary strainer in place in aeration tank.



Secondary strainer minus micro-mesh fabric and outer cover.



Standpipe on the left is on the side of the aeration tank. A sampler is next to it. The secondary strainer tank is on the far right.

FIGURE 4

EQUIPMENT PHOTOGRAPHS

TABLE 1

MICRO-MESH FABRIC SPECIFICATIONS

Nominal Micron Rating	Absolute Micron Rating	Nominal Mesh Count (Openings/inch) (Warp x shoot)	Wire Diameter Inches (Warp x shoot)
		Twilled Dutch Weave	
5 (4-6)	12-14	200 x 1400	.0028/.0016
		Robusta Reverse Dutch Weave	
10 (10-13)	15-18	850 x 155	.0012/.004
20 (18-22)	25-27	600 x 125	.0016/.005
40 (35-45)	48-54	280 x 70	.0035/.008

An FMC SL-144 modified complete mix activated sludge package treatment plant was used for this study. The package plant was supplied with municipal wastewater obtained in continuous supply from an interceptor sewer. The wastewater was screened and comminuted prior to entering the primary clarifier. The primary clarifier has a volume of 9.8 m^3 (347 ft^3 or 2,600 gal) and a surface area of 5.9 m^2 (63.6 ft^2). The clarified influent was then pumped into a 15.2 m^3 (535 ft^3 or 4,000 gal) aeration tank. The primary strainer was placed directly in the mixed liquor at one end of the aeration tank opposite the influent port. The effluent from the primary strainer was fed by gravity into a secondary holding tank with a volume of 4.5 m^3 (158 ft^3 or 1,180 gal). The secondary strainer was mounted in this tank. The final effluent was obtained from the secondary strainer. To keep the solids concentration constant in the secondary tank, a return flow was pumped from the bottom of the cone shaped secondary holding tank back into the mixed liquor. Sludge wasting was accomplished by pumping directly from the aeration tank.

In the secondary holding tank, a cylinder, 0.61 m (2-ft) in diameter and 0.71 m (2.33 ft) high, was connected to the rotating shaft above the basket strainer to minimize radial mixing.

Three FMC samplers were used on the project. Daily composite samples were taken on the primary effluent, the primary strainer effluent, and the final or secondary strainer effluent. The samplers were set to take a sample every 15 minutes. Samples collected on Monday were a composite sample of the weekend. A complete flow diagram for the experimental system is shown in Figure 5.

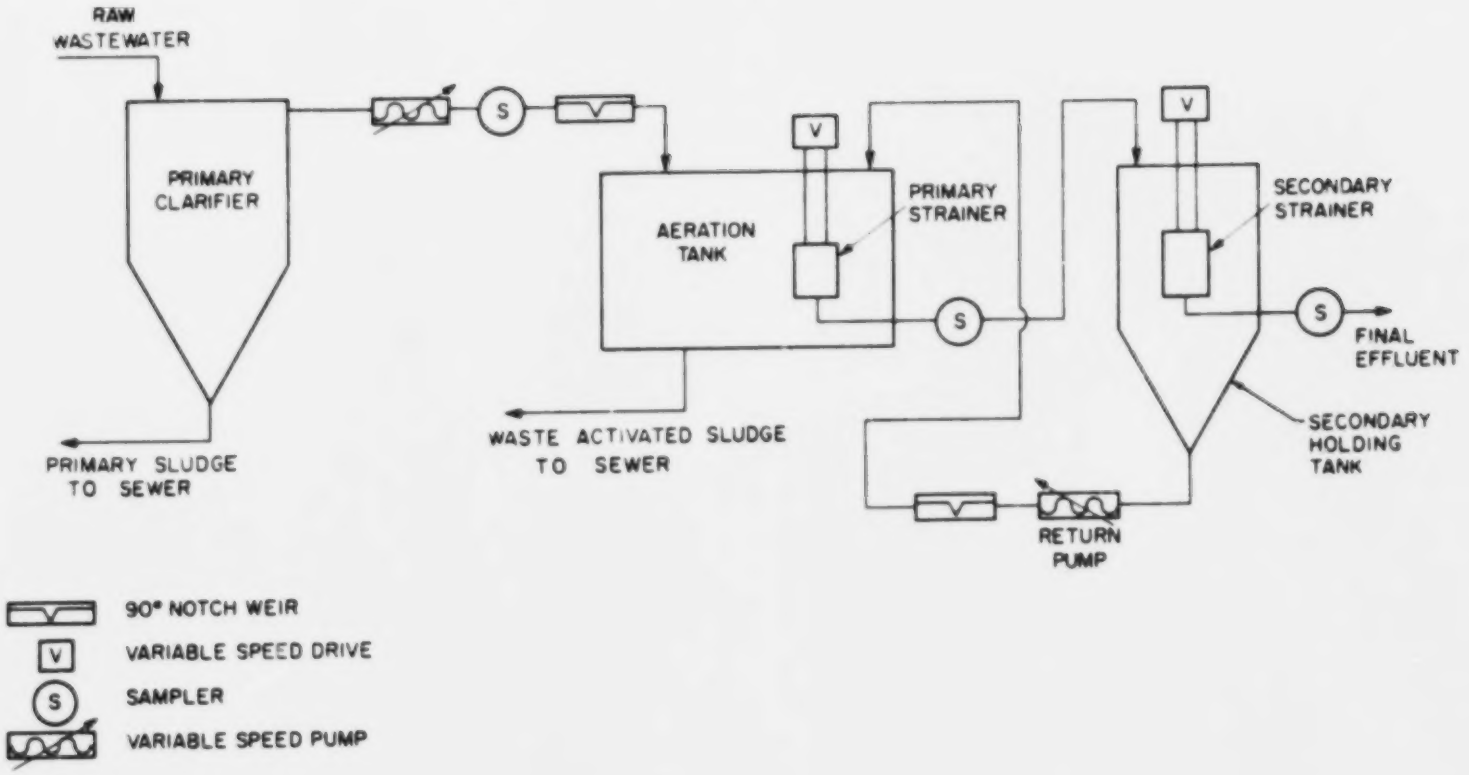


FIGURE 5

DYNAMIC STRAINING FLOW DIAGRAM

Most of the installation work involved mounting the strainers and providing the necessary pumps and piping. The package plant was in place prior to this project. Two - and three-inch PVC pipe was used for the additional piping required by the strainers.

Variable speed pumps were used for both the influent and return flows. These pumps provided the flow adjustment required for evaluation of the strainers.

SECTION V

DESCRIPTION OF OPERATION

Equipment manufacture (Phase I of the project schedule) was completed in September 1972. Installation of equipment (Phase II) was initiated in October 1972. The plant was put in operation the first week in November 1972. One hundred and ninety liters (50 gal) of mixed liquor seed were introduced into the aeration tank along with primary effluent and batch aerated. On November 30, the MLSS concentration reached 340 mg/l. The plant was then fed primary effluent on a continuous basis. Samples were taken daily and some analyses performed. By December 20, the MLSS concentration had reached 4,000 mg/l. The remainder of Phase II was accomplished between December 21, 1972 and February 7, 1973, and consisted of process shakedown and optimization of system hydraulics. Operation and evaluation of the pilot plant test facility (Phase III) began on February 8 and lasted for approximately 12 weeks. Plant operation, system monitoring, and data collection were continuous during this period. Additionally, for the first 10 weeks of Phase III, a series of batch experiments in which system influent flow was temporarily stopped were undertaken to characterize strainer performance as a function of several variables.

Five samples were taken each day during the 12-week operation and evaluation phase. Samples collected on Monday mornings represented 72 hours of continuous weekend sampling. As previously mentioned, composite samples were obtained for the primary effluent, primary strainer effluent, and secondary strainer effluent. Also, grab samples of the secondary return flow and the mixed liquor were taken. A list of the analyses performed on each sample is shown in Table 2. All analytical work was performed in accordance with procedures and methods detailed in "Standard Methods for the Examination of Water and Wastewater," Thirteenth Edition, Washington, D. C. (1971).

Mechanical and operational data were also recorded daily, as indicated in Table 3.

Following process shakedown, the experimental program to characterize the dynamic strainers was initiated on February 8, 1973. The variables evaluated during this 10-week segment of Phase III included nominal pore size of the strainer fabrics, suspended solids concentrations in the aeration and secondary holding tanks, rotational speed of the strainers, and hydraulic head in both tanks.

An outline of the experimental characterization program is given in Table 4. Initially, a 20-micron fabric was put on the primary strainer and a 10-micron fabric on the secondary strainer. For the first characterization tests on the primary strainer, the MLSS concentration was adjusted to about 2,500 mg/l. The drum speed was set and the

TABLE 2

SAMPLING AND ANALYSES SUMMARY

SAMPLE NUMBER	TYPE	LOCATION
1	Composite	Primary Effluent
2	Grab	Mixed Liquor
3	Composite	Primary Strainer Effluent
4	Grab	Secondary Strainer Return
5	Composite	Secondary Strainer Effluent

SAMPLE	TSS	VSS	TOC	SOC	COD	BOD_5	Total N	NH_3-N	pH	DO
1	X	X	X	X	Z	Y	Z	Z	X	
2	X	X								Z
3	X	X	X	X				Z	X	
4	X	X								
5	X	X	X	X	Z	Y	Z	Z	X	

X - Daily, Monday through Friday
Y - Monday, Wednesday, and Friday
Z - Occasionally

liquid level raised to achieve the maximum head allowed by the tank. Then the effluent butterfly valve was opened and the influent flow was stopped. As the liquid level dropped, the flow and corresponding head were recorded. This flow was measured with the use of a 20 l (5.3 gal) container and stop watch. Head was recorded as the difference in the liquid levels of the tank and the standpipe. Suspended solids samples were taken at several different head measurements. When the liquid level dropped enough so that the flow stopped, the strainer was set at a new rotational speed and the aforementioned procedure repeated. This testing method was changed slightly to accommodate the higher specific flow rates obtained at higher drum speeds.

The head versus flow curves had an optimum flow at a head slightly larger than the head at which the flow stopped. At the higher flows, the level in the tank dropped too fast to allow the screen to sufficiently clean itself before the head dropped past the optimum point. To eliminate this problem, the tests were started with a low head that produced no flow for a given strainer peripheral velocity. Then the head was slowly increased by introducing influent in controlled amounts. This procedure was followed throughout the remainder of the testing program. A comparison in Figure 6 of the head versus flow curves for the increasing head test procedure and the decreasing head test procedure shows the marked contrast.

TABLE 3

OPERATIONAL DATA OUTLINE

PARAMETERS MEASURED	LOCATION
LIQUID FLOW	Primary Effluent Secondary Strainer Return
AIR FLOW	To Aeration Tank
STRAINER SPEED	Primary Strainer Secondary Strainer
HYDRAULIC HEAD	Primary Strainer Secondary Strainer
SONIC GENERATOR AMPS	Primary Strainer Secondary Strainer
TURBIDITY	Primary Strainer Effluent Secondary Strainer Effluent
DISSOLVED OXYGEN	Aeration Tank

During the first segment of the characterization program, head versus flow curves were obtained with the primary strainer for several drum speeds at a MLSS level of 2,500 mg/l. Similar curves were also recorded for a MLSS concentration of 1,800 mg/l. The same procedure (recording flow as head increased) was used to obtain head versus flow curves for the secondary strainer at three different suspended solids levels and several different drum speeds. During this phase of high flow rates, the fabric area was reduced by 74 percent to eliminate back pressure effects in the effluent piping. Plastic sheet was wound around the drum and taped in place to blind the fabric.

For the second segment of the characterization program, a 40-micron fabric was placed on the primary strainer. The 10-micron fabric remained on the secondary strainer. Data were obtained for the primary strainer at MLSS levels of 2,500, 3,500, and 6,000 mg/l. The secondary strainer was again characterized at three different suspended solids levels.

TABLE 4

OUTLINE OF STRAINER CHARACTERIZATION PROGRAM

I. Fabric Combination - 20-micron, 10-micron (Feb. 8)

- A. Primary 20-micron
  1. MLSS - 2,570 mg/l - Obtained head (H) versus flow (Q) curves for tip speeds of 188, 376, 564, 752 ft/min
  2. MLSS - 1,830 mg/l - Changed procedure to increasing head - Obtained head (H) versus flow (Q) curves for speeds of 376 and 752 ft/min
- B. Secondary 10-micron
  1. Tank SS - 130 mg/l - H versus Q curves - 188, 376, 564 ft/min
  2. Tank SS - 40 mg/l - Changed procedure to increasing head. H versus Q curves - 564 and 752 ft/min
  3. Tank SS - 90 mg/l - H versus Q curves - 564 and 752 ft/min

II. Fabric Combination - 40-micron, 10-micron (March 8)

- A. Primary 40-micron
  1. MLSS - 2,370 mg/l - H versus Q curves - 376, 564, 752 ft/min
  2. MLSS - 3,700 mg/l - H versus Q curves - 188, 376, 564, 752 ft/min
  3. MLSS - 6,140 mg/l - H versus Q curves - 188, 376, 564, 752 ft/min
- B. Secondary
  1. Tank SS - 245 mg/l - H versus Q curves - 564, 752, 1,128 ft/min
  2. Tank SS - 166 mg/l - H versus Q curves - 376, 564, 752, 1,128 ft/min
  3. Tank SS - 112 mg/l - H versus Q curves - 376 ft/min

III. Fabric Combination - 10-micron, 5-micron (April 1)

- A. Primary 10-micron
  1. MLSS - 6,630 mg/l - H versus Q curves - 188, 376, 564, 752 ft/min
  2. MLSS - 9,100 mg/l - H versus Q curves - 188, 376, 564, 752 ft/min
  3. MLSS - 12,200 mg/l - H versus Q curves - 188, 376, 564, 752 ft/min
- B. Secondary 5-micron
  1. Tank SS - 48 mg/l - H versus Q curves - 232, 376, 564, 752 ft/min
  2. Tank SS - 300 mg/l - H versus Q curves - 564 ft/min

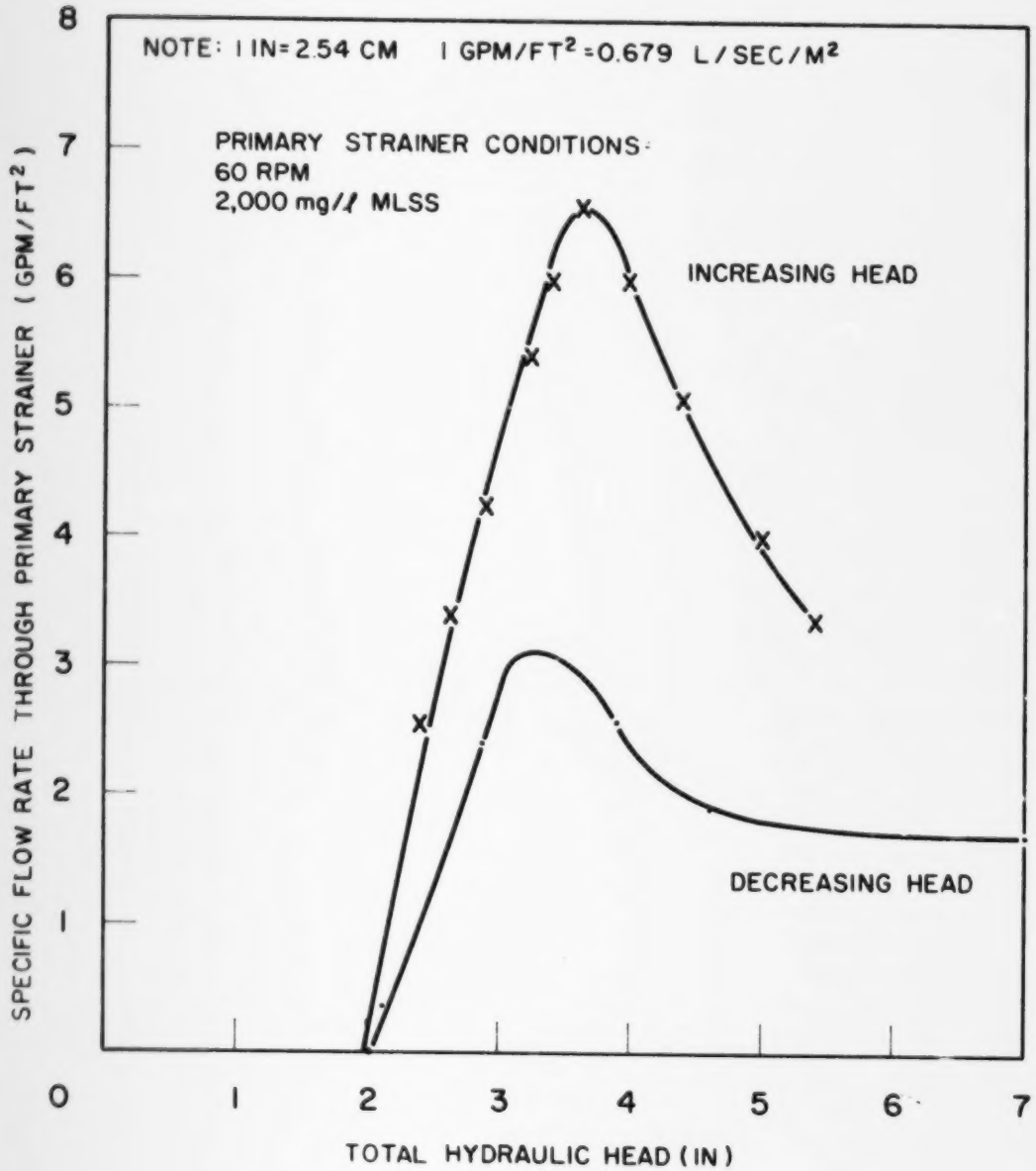


FIGURE 6

A COMPARISON OF INCREASING
AND DECREASING HEAD TESTS

A 10-micron fabric was used on the primary strainer and a 5-micron fabric on the secondary strainer for the last segment of the characterization program. Head versus flow curves were compiled for the primary strainer at MLSS levels of 6,500, 9,000, and 12,000 mg/l. The 5-micron fabric on the secondary strainer was characterized at two different suspended solids levels.

Following the characterization of the individual strainer variables, the entire system was operated continuously for about two weeks, beginning April 18. During the strainer characterization testing program, the 10-micron fabric yielded the best results on the primary strainer. Therefore, the 10-micron primary/5-micron secondary fabric combination was used on the strainers during the uninterrupted continuous flow segment of Phase III. The MLSS level was held around 8,000 mg/l. The system was monitored in the same manner as during the process shakedown and strainer characterization work.

SECTION VI

DISCUSSION

The ultimate feasibility of dynamic straining is dependent on two performance parameters; specific flow rate and suspended solids removal. Both of these will be discussed in terms of the variables analyzed during the testing period and day-to-day continuous performance.

SPECIFIC FLOW RATES

Specific flow rates were affected by four variables; nominal opening size of the micro-fabric, unstrained suspended solids concentration, strainer rotational speed, and hydraulic head.

The rotation of the drum causes a centrifugal pumping head. Differential heads were measured as the difference between the liquid level at the tank wall and the standpipe overflow as shown in Figures 2 and 3. When no influent is entering the system, this difference is the pumping head. If the liquid head in the tank outside the drum is increased and influent flow is introduced to the system causing a discharge from the standpipe, some friction head loss occurs. These friction losses can be assumed to take place across the micro-fabric, as the losses through the piping are minimal at normal flows. The net head or driving head across the micro-fabric is the total head measured during experimentation minus the centrifugal pumping head at zero flow, which is composed of internal and external pumping heads.

Net head is a more meaningful parameter in determining straining characteristics. Different sizes and configurations of strainers and tanks will have unique centrifugal pumping heads. Similar results should be expected when performances of different strainers with the same fabric covering are compared at the same net heads.

The theoretical pumping heads can be approximated by using the Navier-Stokes equations in cylindrical coordinates for the steady flow of an incompressible fluid around a vertical axis. The radial variation of pressure head due to rotation is given by Equation 1, which represents the elevation of the liquid surface at increasing distance from the axis of rotation, Daily and Harleman, (2).

$$\frac{dH}{dr} = \frac{V^2}{gr} \qquad (1)$$

Integration over the radial distance from the internal baffle to the drum provides an equation for the internal pumping head by making the assumption that the internal layer of water between the internal baffling and the drum has the same velocity as the drum.

$$H_{pi} = \frac{V^2}{g} \ln\left(\frac{r_2}{r_1}\right) \qquad (2)$$

Where,

H_{pi} = Internal pumping head in feet

V = Tangential velocity of water in ft/sec

r = Radial distance from rotational axis in inches

g = Gravitational constant = 32.2 ft/sec^2 (9.8 m/sec^2)

r_2 = Radius of drum in inches

r_1 = Radius of exterior edges of internal baffling in inches

Plots of theoretical H_{pi} versus the velocity of the drum for the primary and secondary strainer are shown in Figures 7 and 8, respectively.

To calculate the external pumping head the velocity profile of the water outside the drum had to be obtained. Water velocities in the secondary tank were measured with a current meter at different distances from the drum. Velocity profiles at zero flow and with a specific flow rate of 1.2 l/sec/m^2 (1.8 gpm/ft^2) are shown in Figure 9 for a drum peripheral velocity of 1.83 m/sec (6 ft/sec). These velocity measurements are averages of measurements taken at several different depths.

Ignoring wall effects, the following linear equation represents a fair approximation of the water velocity profile outside the drum at zero flow:

$$V = 3(\text{ft/sec}) - 0.06\left(\frac{\text{ft}}{\text{sec-in}}\right)r \qquad (3)$$

Where,

V = Water velocity in ft/sec

r = Radial distance from vertical axis of drum in inches

This equation, shown graphically in Figure 9, can be used to calculate the theoretical external pumping head. When this value was added to the theoretical internal pumping head, the sum was within 10 percent of the value of the actual pumping head obtained by experimentation. Substituting the velocity function (Equation 3) in Equation 1 and integrating for the values of r from the outer edge of the drum to the tank wall, yields a value for external pumping head for the secondary

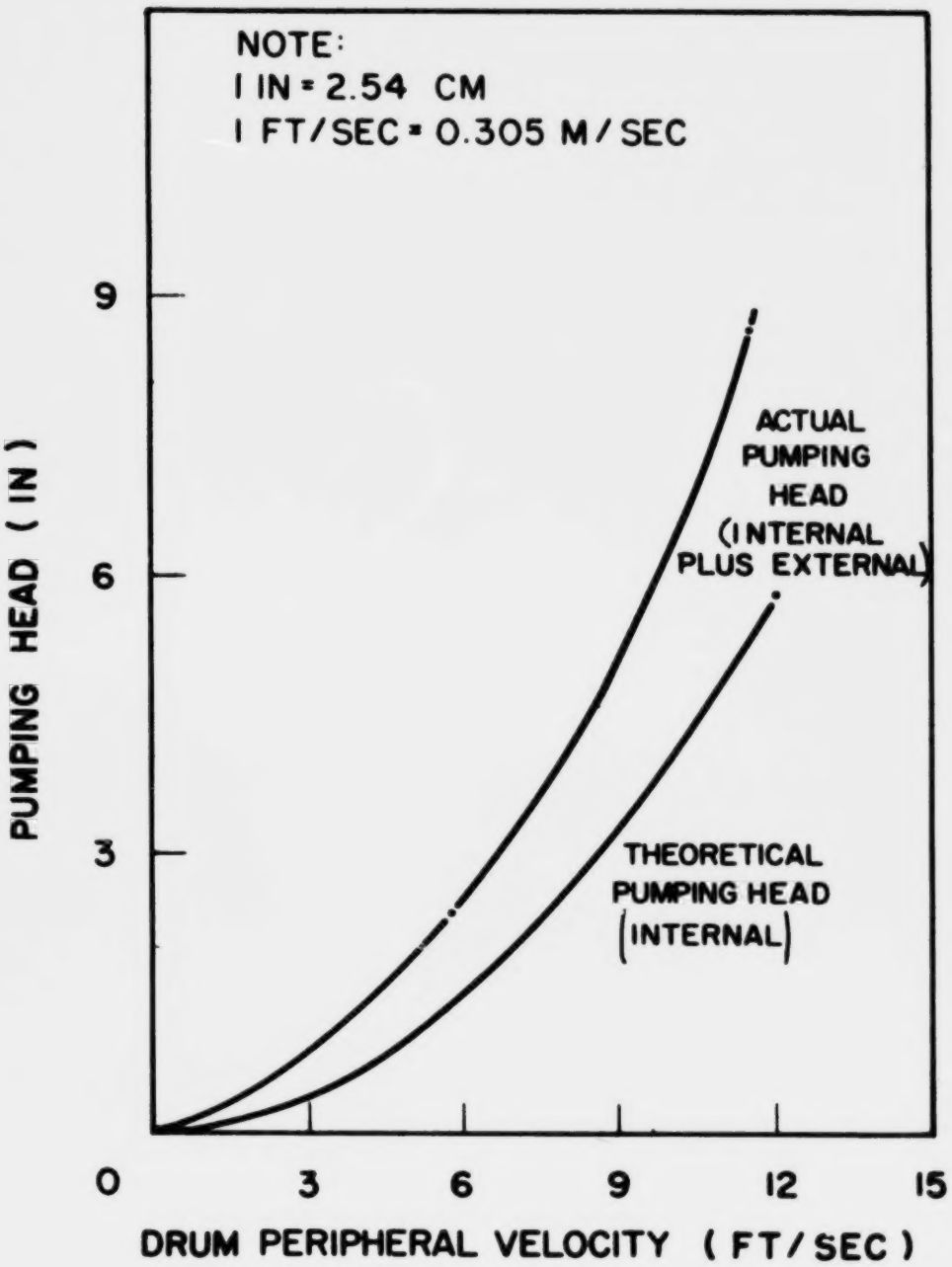


FIGURE 7

PRIMARY STRAINER INTERNAL
PUMPING HEAD

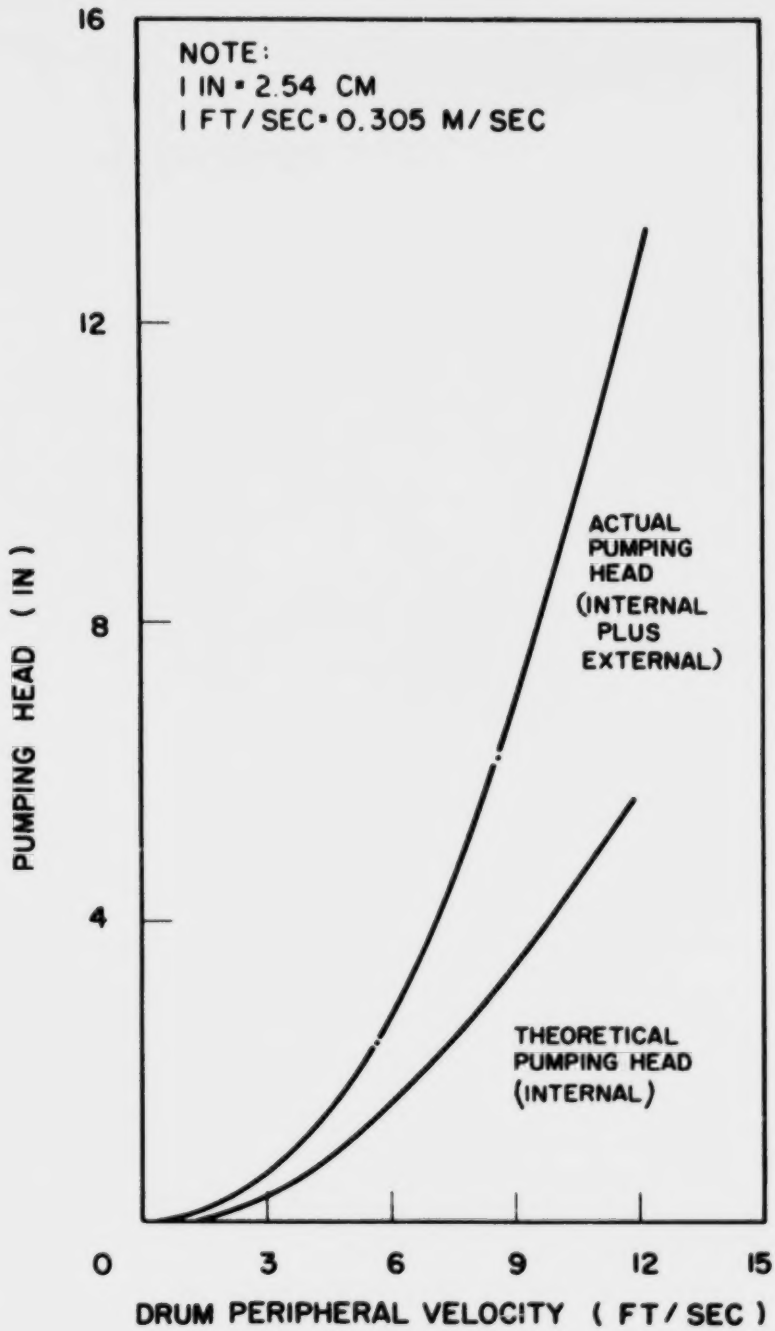


FIGURE 8

SECONDARY STRAINER INTERNAL
PUMPING HEAD

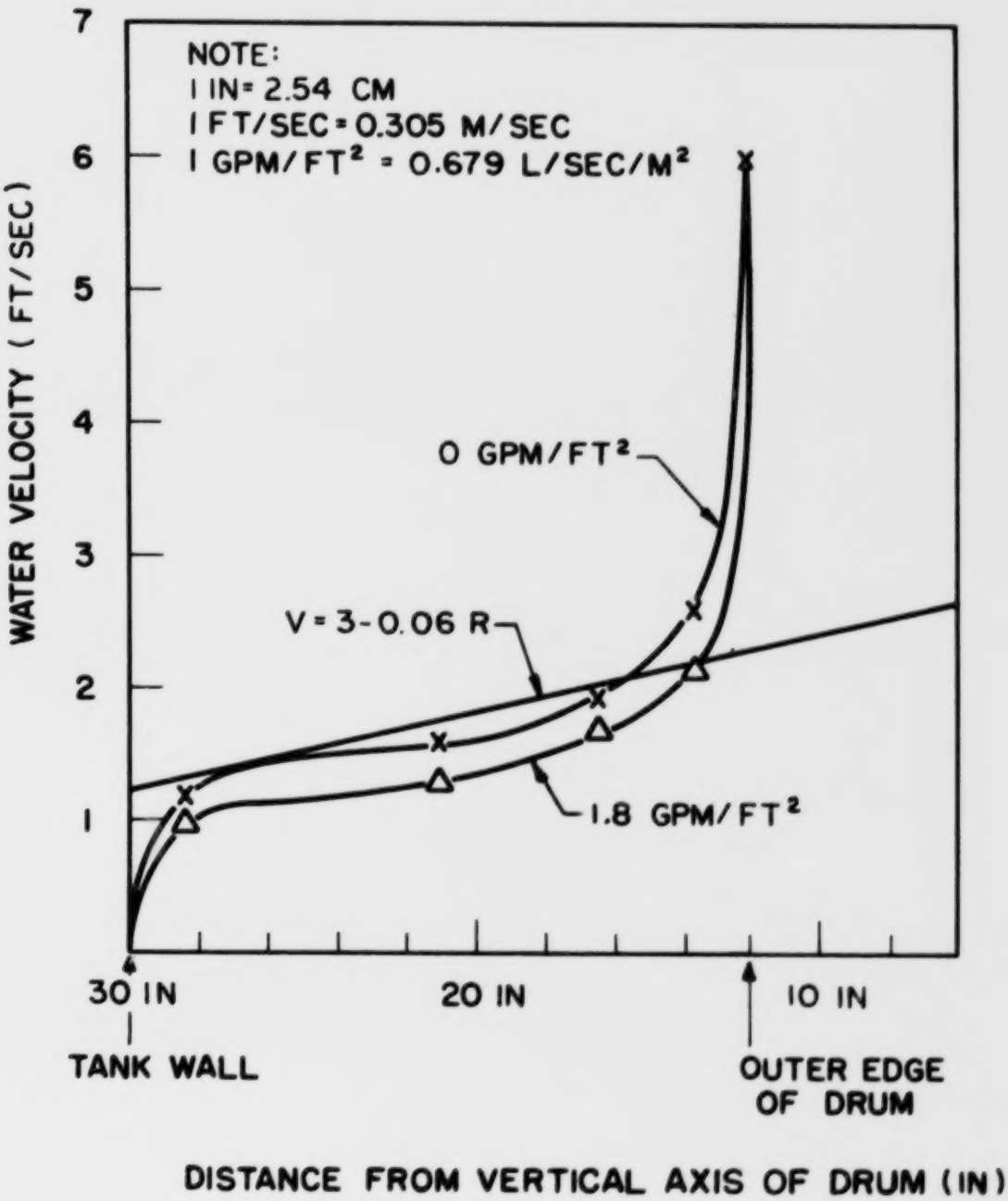


FIGURE 9

SECONDARY TANK WATER VELOCITY
PROFILES AT DIFFERENT FLOW RATES

strainer of 2.97 cm (1.17 in) at a drum peripheral velocity of 1.83 m/sec (6 ft/sec).

$$H_{pe} = \frac{9}{32.2} \ln \frac{30}{12} - \frac{0.36}{32.2} (30-12) + \frac{0.0036}{64.4} (900-144)$$

$$H_{pe} = 0.09712 \text{ ft} = 1.17 \text{ in}$$

Utilizing Equation 2 or Figure 8, a value of the internal pumping head of 2.97 cm (1.17 in) is obtained at a drum peripheral velocity of 1.83 m/sec (6 ft/sec). Therefore, the total pumping head for this drum velocity is:

$$H_{Total} = 2.97 + 2.97 = 5.94 \text{ cm } (2.34 \text{ in})$$

The external pumping head is more pronounced in the secondary strainer than in the primary strainer, particularly at higher drum velocities, because of the circular holding tank and the absence of aeration. The velocity profile on the outside of the drum changes as flow through the strainer increases and so the pumping head also changes. The actual pumping head curves in Figures 7 and 8 are based on averages from all the data taken when there was no flow through the respective strainers.

The effect of head on specific flow rate was consistent throughout the program. As previously shown in Figure 6, the specific flow rate increased as the measured head increased until a peak specific flow rate was attained. Then, as the head continued to increase, the specific flow rate dropped off gradually. An explanation of these observations, based on the data obtained, is that this phenomenon is a result of the opposing forces acting on the suspended solids being strained. The combined effects of the strainer rotation and ultrasonics force the solids away from the fabric, while the hydraulic head forces the solids toward the screen. On the low-head side of the peak, the combined forces of rotation and ultrasonics are larger than the force due to the head. Therefore, the specific flow rate through the strainer continues to increase with increasing liquid head. Then, when these opposing forces along with other head losses and viscous effects balance, the maximum specific flow rate is reached. The viscous effects include the force exerted on the solids by the flowing liquids. On the high-head side of the peak, the force due to hydraulic head exceeds the cleaning effect of the other two forces and the specific flow rate decreases.

The data show that as rotational speed increases, the hydraulic head required for maximum specific flow rate also increases. The shape of a set of total head versus specific flow rate curves, at different rotational velocities, is similar for both strainers and is illustrated in Figure 10. Figure 11 shows a set of net head versus specific flow rate curves. The shape of the curves is again characteristic of both strainers.

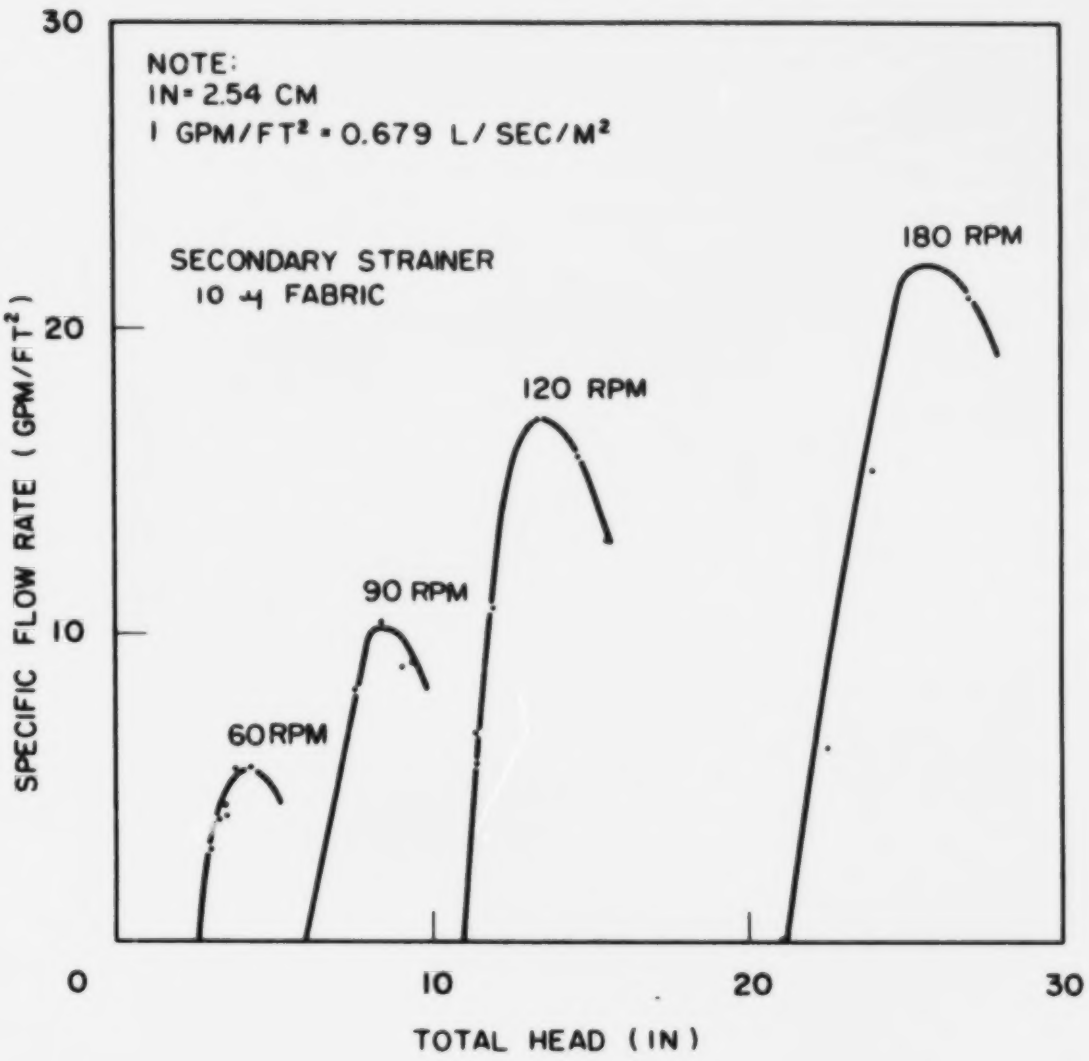


FIGURE 10

TOTAL HYDRAULIC HEAD CURVES
AS A FUNCTION OF ROTATIONAL SPEED

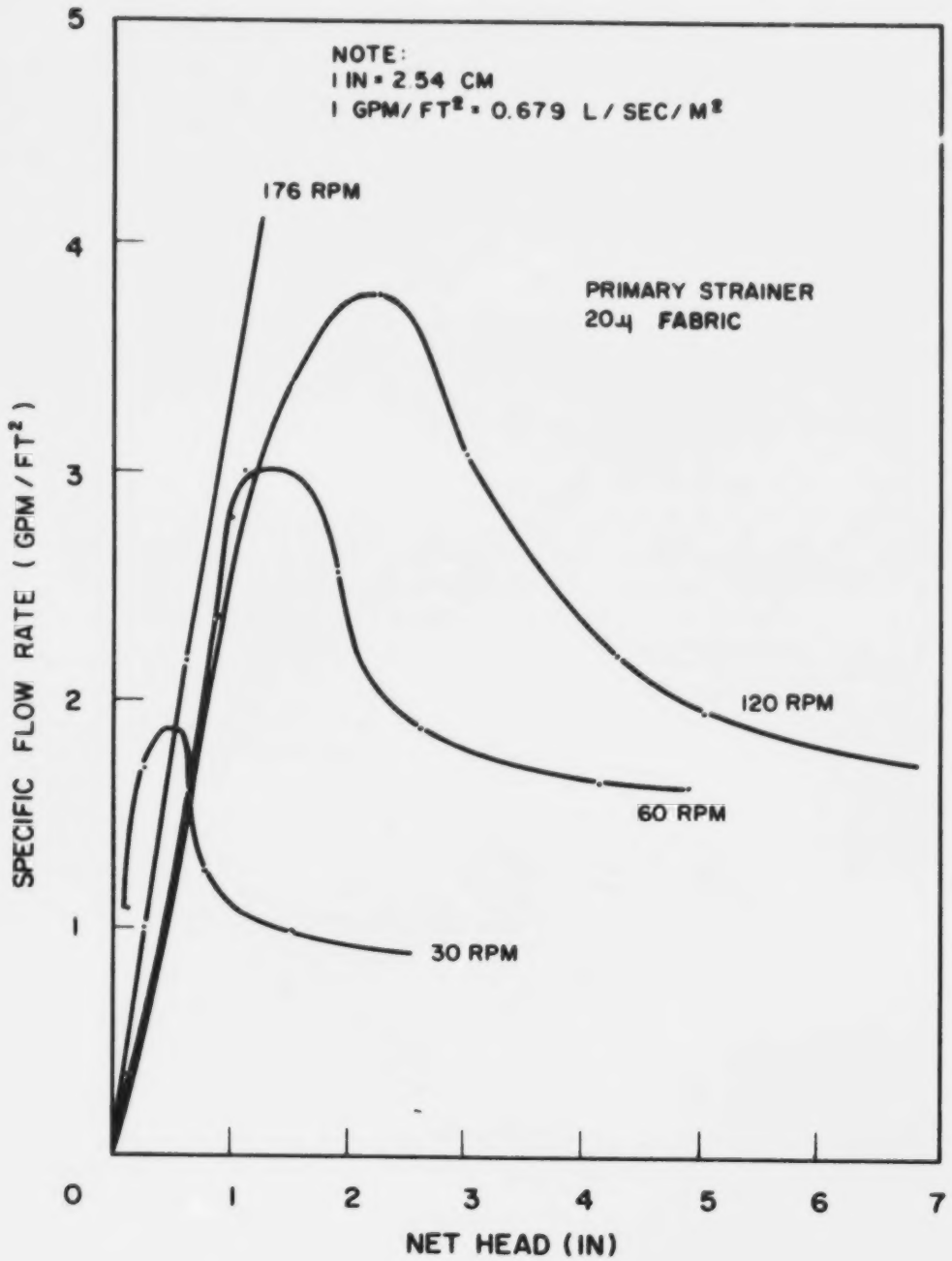


FIGURE 11

NET HYDRAULIC HEAD CURVES AS
A FUNCTION OF ROTATIONAL SPEED

The effect of rotational speed (peripheral velocity) on specific flow rate was also quite consistent during the test program. The specific flow rate increased as the velocity increased. This result can be explained on the basis of the theory proposed in the previous paragraphs. The greater speed provides a larger hydraulic and ultrasonic rotational cleaning due to a smaller and more energetic boundary layer around the drum and more frequent ultrasonic cleaning. Therefore, greater liquid head can be applied before the hydraulic head force on the solids exceeds the opposing cleaning forces.

Another factor in the character of the boundary layer is the flow into the drum. As the flow increases, the water with slower velocities relative to the drum is swept into the drum bringing water with higher velocities relative to the drum closer to the drum with more cleaning energy.

This phenomenon can explain why peak specific flow rates were significantly lower when the liquid head was quickly lowered past the peak point in early testing. Starting at higher heads caused the screens to become immediately partially blinded with solids. The head in the tank would drop quickly as the peak specific flow rate was approached, not allowing sufficient time for the fabric to clean itself to obtain satisfactory specific flow rates, which would have in turn further increased the cleaning efficiency.

The effect of MLSS concentration on primary strainer specific flow rate was predictable in most cases. As the level of MLSS increased, the specific flow rate decreased. This was attributed to greater clogging of the micro-fabric with solids. The same effect was experienced for all three mesh sizes used. However, the solids levels used with the secondary strainer were not high enough to yield a similar conclusive result.

The effect of micro-fabric nominal opening size on specific flow rate was unexpected, although static, clean water straining tests proceeded as anticipated. Clean water total hydraulic head versus specific flow rate curves for four different micro-fabric sizes are shown in Figure 12. The 40-micron and 10-micron fabrics were also evaluated on the primary strainer under similar conditions at a MLSS level of about 6,000 mg/l. The 10-micron fabric yielded a maximum specific flow rate of 8.1 l/sec/m^2 (12 gpm/ft^2). The maximum specific flow rate of the 40-micron fabric was only 2.3 l/sec/m^2 (3.36 gpm/ft^2). The 20-micron fabric was never evaluated at the same MLSS concentration as the 10-micron fabric. However, the maximum specific flow rate achieved with the 20-micron fabric was 10 l/sec/m^2 (14.8 gpm/ft^2) at a MLSS level of about 1,800 mg/l. Based on previously mentioned results on the effect of MLSS level on primary strainer specific flow rate, the 10-micron fabric was judged to have exhibited the best overall performance. All three micro-fabrics tested on the primary strainer were of the same Robusta weave.

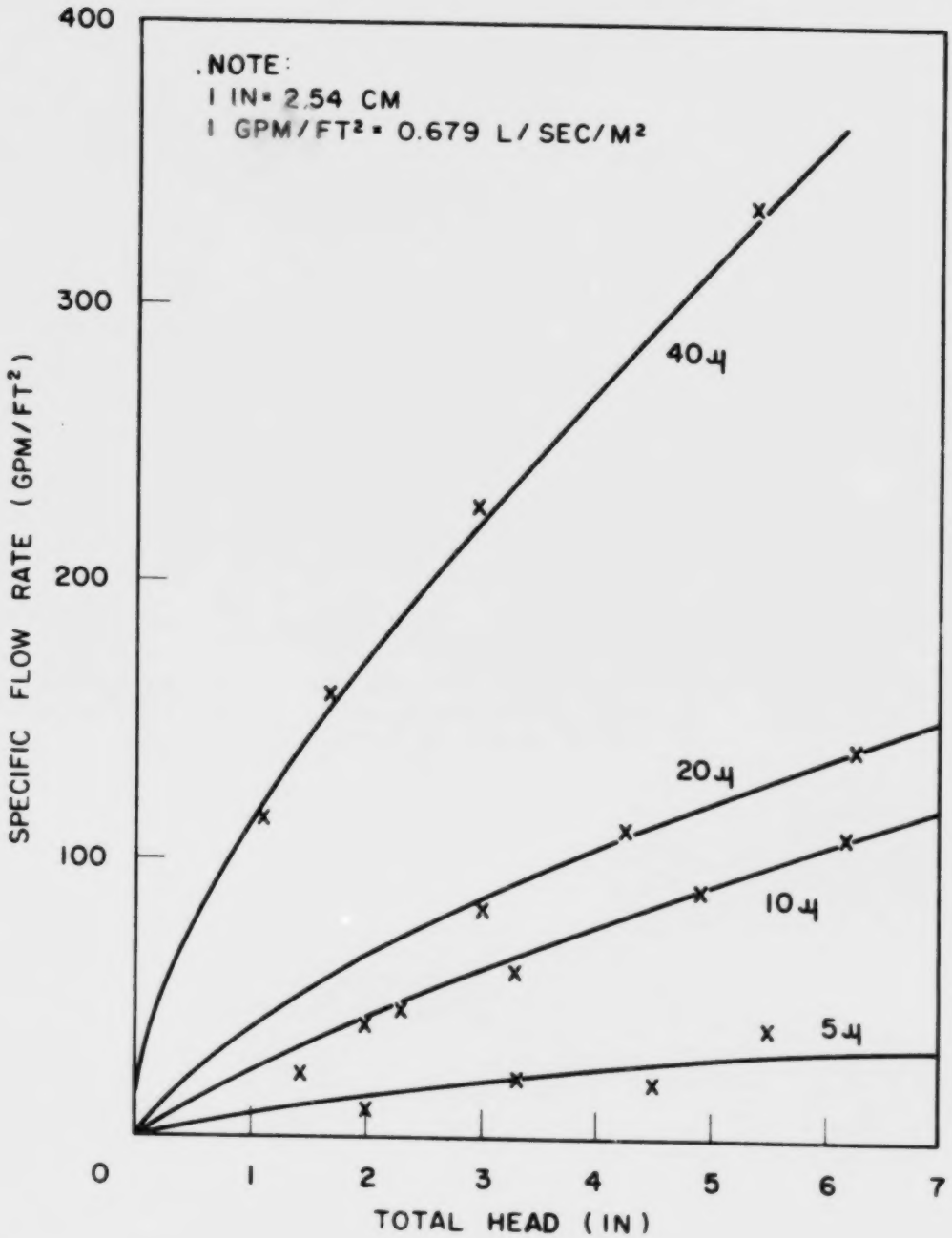


FIGURE 12

CLEAN WATER TEST OF MICRO-FABRICS

One possible explanation for the anomalous performance of the fabrics is that this phenomenon is associated with the nature of the biomass. Possibly, the 10-micron fabric allows less entanglement of filamentous microorganisms and, therefore, is more easily cleaned. Also, the more rigid and porous fabrics may not be cleaned as effectively by the ultrasonic energy. Obviously, work in this area is not conclusive.

Used with the secondary strainer, the 10-micron fabric provided a maximum specific flow rate of 17 l/sec/m^2 (25 gpm/ft^2). For similar suspended solids levels, the 5-micron fabric yielded only 1.9 l/sec/m^2 (2.8 gpm/ft^2). This 5-micron fabric was a Dutch-Twill weave which has inferior specific flow rate capacities.

SUSPENDED SOLIDS REMOVALS

During the testing program, suspended solids removals were affected by three of the test variables; nominal pore size, suspended solids concentration, and the peripheral velocity of the strainer.

The effect of peripheral velocity on suspended solids removal was quite consistent throughout the testing program. For both the primary and secondary strainers and for all four fabrics tested, the effluent quality decreased with an increase in peripheral velocity.

Two possible explanations for this observation have been proposed. As the velocity increases, more of the floc particles near the fabric are broken down and pass through the fabric. Also, at lower speeds, a solids blanket may accumulate due to reduced frequency of ultrasonic cleaning and reduced hydraulic cleaning. This would help to filter out the smaller particles. For an increase in peripheral velocity from 1.9 m/sec (376 ft/min) to 3.8 m/sec (752 ft/min), the effluent suspended solids increased 200 to 400 percent.

The suspended solids levels in the respective tanks affected suspended solids removals. As the suspended solids concentrations in the tanks increased, effluent suspended solids also increased. However, the percent solids removed by the strainer also increased. Similar results were obtained with both strainers for all fabric sizes.

The effect of fabric nominal pore size on suspended solids removal was predictable. The larger pore sizes allowed more suspended solids to pass through. For the most part, head did not significantly affect suspended solids removal.

All graphs and data tabulations obtained during the strainer characterization test program are presented in Appendices A and B. The information contained in these graphs and tabulations is summarized below.

On the primary strainer, the 10-micron fabric was more effective in removing MLSS than either the 20-or 40-micron fabrics tested. In the MLSS range of 6,240-6,840 mg/l, residual suspended solids were less than 15 mg/l at a rotational speed of 30 rpm and less than 30 mg/l at 60 rpm on the 10-micron fabric. This yielded peak specific flow rates, respectively, of 1.2 l/sec/m^2 (1.7 gpm/ft^2) at a total head of 4.6 cm (1.8 in) and 3.3 l/sec/m^2 (4.8 gpm/ft^2) at a total head of 9.7 cm (3.8 in). Increasing the rotational speed to 90, then to 120 rpm increased the peak throughout rate to 4.5 l/sec/m^2 (6.7 gpm/ft^2) at a total head of 16.8 cm (6.6 in) and 8.1 l/sec/m^2 (12.0 gpm/ft^2) at a total head of 30.5 cm (12.0 in), respectively. However, residual suspended solids increased at the higher throughput rates to 40-80 mg/l at 90 rpm and 90-120 mg/l at 120 rpm. Increasing the rotational speed further to 150 rpm resulted in excessive solids breakthrough and a substantial drop in peak specific flow rate.

In the MLSS range of 8,760-9,540 mg/l, the primary strainer 10-micron fabric produced residual suspended solids of 20-25 mg/l at 30 rpm, 30-35 mg/l at 60 rpm, 50-80 mg/l at 90 rpm, and 85-95 mg/l at 120 rpm. Peak specific flow rates were very similar to those observed in the MLSS range of 6,240-6,840 mg/l for rotational speeds up to 90 rpm. At 120 rpm, however, the peak throughput rate was only 5.4 l/sec/m^2 (7.9 gpm/ft^2) compared to 8.1 l/sec/m^2 (12.0 gpm/ft^2) at the lower MLSS level.

As the MLSS concentration was further increased to 11,520-12,720 mg/l, both throughput rates and residual suspended solids deteriorated significantly. For example, at 60 rpm, residual suspended solids were in the 65-75 mg/l range and the peak specific flow rate attained was 1.2 l/sec/m^2 (1.8 gpm/ft^2). At 90 rpm, the corresponding values were 90-100 mg/l and 2.2 l/sec/m^2 (3.2 gpm/ft^2).

On the secondary strainer, the 5-micron and 10-micron fabrics exhibited approximately the same capability for removing residual suspended solids contained in the primary strainer effluent. However, the attainable throughput rates on the 5-micron fabric were only 1/5 to 1/10 those achieved with the 10-micron fabric. Percentage suspended solids removal on the 10-micron fabric increased with increasing concentration of solids in the secondary holding tank up to 260 mg/l. Concentrations above 260 mg/l were not evaluated.

Suspended solids removals on the secondary strainer 10-micron fabric were as follows:

1. For a rotational speed of 90 rpm, suspended solids removals averaged 50-65 percent at a holding tank suspended solids concentration of 30-50 mg/l, 85-90 percent at 90-100 mg/l, 85-90 percent at 160-170 mg/l, and 90 percent at 225-230 mg/l.

2. For 120 rpm, suspended solids removals averaged 50-65 percent at a holding tank suspended solids concentration of 30-35 mg/l, 80-85 percent at 80-100 mg/l, 80-85 percent at 165-170 mg/l, and 90 percent at 250-260 mg/l.

3. For 180 rpm, suspended solids removals averaged about 75 percent at a holding tank suspended solids concentration of 160-170 mg/l and 85 percent at 250-260 mg/l.

Peak specific flow rates for the secondary strainer 10-micron fabric ranged from 6 to 10 l/sec/m^2 (9 to 14 gpm/ft^2) at 90 rpm and from 8 to 17 l/sec/m^2 (12 to 25 gpm/ft^2) at 120 rpm. In both cases, the higher throughput rates corresponded to the lower holding tank suspended solids concentrations. For the two holding tank suspended solids concentrations tested at 180 rpm, the peak throughput rate averaged 14-15 l/sec/m^2 (21-22 gpm/ft^2). Peak specific flow rates occurred at total heads of 20-23 cm (8-9 in) at 90 rpm, 36-41 cm (14-16 in) at 120 rpm, and 64-69 cm (25-27 in) at 180 rpm.

DAILY OPERATION

After process shakedown, the entire experimental system was operated continuously, whenever possible. Minor interruptions occurred periodically including mechanical failures and operational upsets. However, daily samples and operating data were obtained on a near-continuous basis.

The hydraulics of the package treatment plant were inadequate to handle the large flows utilized during the strainer characterization testing program. The influent pump could supply only about 1.3 l/sec (20 gpm) which was equivalent to a specific flow rate of about 2.7 l/sec/m^2 (4 gpm/ft^2). During the characterization programs, an additional high-rate pump was used to help fill the tanks.

A second hydraulic problem was the primary effluent piping. As influent flows became very large, the head loss through this section became limiting. During specific evaluation tests on the primary strainer, this line was bypassed. Despite these hydraulic limitations, daily monitoring and operation permitted observation of several very important operational parameters.

One area of special interest was the shape of the head versus specific flow rate curves. Daily operation supplied an opportunity to check the validity of these curves over a longer period than possible with each specific test. Because of the hydraulic limitations, the strainers could be evaluated continuously only at the lower rotational speeds. Under these conditions, it was found that daily operation did closely parallel the experimentally obtained head versus specific flow rate curves.

A peripheral velocity of 1.9 m/sec (376 ft/min) was frequently used for day-to-day operation. At this velocity, the liquid level could be dropped to equal the pumping head. The influent flow was then usually set at a rate slightly below the maximum indicated for those conditions. The liquid level would thereafter rise until the necessary head on the strainer was achieved. Balancing of flows was easily maintained. If the influent flow exceeded the peak strainer throughput capability for a specific rotational speed, the liquid head would continue to increase until the tank under investigation overflowed. The most obvious remedy to this problem was to increase the strainer rotational speed to accommodate the increased flow. However, since automatic control of rotational speed was not available, a float switch was used to shut off the influent pump if the liquid level rose too high. The pump would start again when the head had fallen beneath a predetermined point.

The nature of the biomass was another area of special interest. For this particular project, there was not sufficient time to adequately document the effect of biomass on strainer operation. However, some work was done and observations made based on that work. Filamentous growth prevailed in the mixed liquor. Previous pilot plant work at this site also experienced similar mixed liquor cultures. This type of biomass proved to be very strainable.

The dynamic strainer system also appeared to be selective for the filamentous microorganisms. Twice during the experimental program the primary strainer had to be removed from the system to make repairs on the drive unit. During the repair period, the system was operated conventionally with a secondary clarifier for a few days. When the primary strainer was returned to the system, suspended solids removals were quite poor initially. Then, after several days, the biomass would readjust, become more filamentous, and suspended solids removals would improve.

The strainability of the biomass was also affected by the organic (F/M) loading. During the third phase of the characterization testing program, the MLSS concentration was raised to about 12,000 mg/l by supplementing the primary effluent feed with beet molasses. Following these tests, addition of beet molasses was stopped. The system continued to operate effectively for about three days. Then, both the specific flow rates and suspended solids removals started to deteriorate. During this period, the organic loading dropped below 0.05 kg BOD_5/day/kg MLVSS (0.05 lb BOD_5/day/lb MLVSS). Several different mechanical adjustments were made in an attempt to improve strainer performance, but were unsuccessful. Beet molasses was then added again, and after two days the specific flow rate improved.

Limited studies were undertaken to define the settling characteristics of the primary strainer effluent. Figure 13 is a graph showing the percentage of solids with settling velocities equal to or less than prescribed values. The procedure for obtaining settling velocities

for unhindered settling was obtained from the Link-Belt Division of FMC Corporation, (3). These settling results are predictably poor due to the very fine nature of the discrete particles which pass through a 10-micron fabric. Additional studies should be undertaken to determine settleability of varying primary strainer effluents. Chemical addition may be necessary to enhance flocculation of these fine solids. These studies would be important in determining the capability of dynamic straining to upgrade existing activated sludge treatment plants. Dynamic straining could decrease the solids loading on an existing secondary clarifier where solids thickening capacity had been exceeded. At the same time, it would permit maintenance of a higher MLVSS concentration in the aeration tank, thereby lowering the organic (F/M) loading without increasing the size of the aeration facilities.

The results of day-to-day continuous operation during the process shakedown and experimental study phases are summarized in detail in Appendix C.

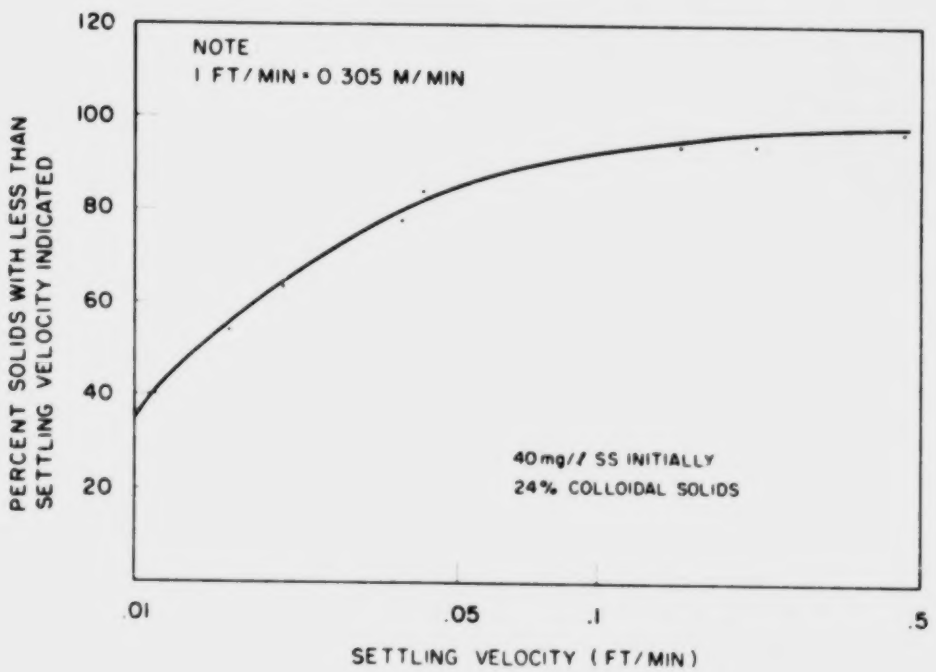


FIGURE 13

SETTLING VELOCITIES OF PARTICLES
IN PRIMARY STRAINER EFFLUENT

SECTION VII

ECONOMIC ANALYSIS

An economic comparison between activated sludge plants utilizing dynamic straining clarification versus gravitational clarification would not be sufficient without comparing the economic changes in other processes which dynamic straining can alter. Aeration tank volumes and sludge handling facility requirements are both altered by dynamic straining. An economic comparison of 3,785 and 37,850 m^3/day (1 and 10 mgd) plants has been calculated using Patterson, et al, (4), as a basis for estimating costs on every unit process except dynamic straining.

The cost estimate for dynamic straining has been evaluated using FMC's current basic production model for which the process specifications principally cover lagoon effluent applications. The production model has approximately 6.5 m^2 (70 ft^2) of screening area. A cost of $58,600 per strainer has been established for estimating purposes in this report. Tanks for secondary strainers would add about $5,000 to the cost of each strainer. Larger units, design improvements, and combined tankage for secondary straining should bring the cost down considerably.

For estimating annual costs, a conservative fabric life of one year was used. The fabric will cost approximately $16/$m^2$ ($15/$ft^2$) to replace. Power requirements are approximately 1.6 kw/m^2 (0.2 hp/ft^2) to rotate the drum and 0.37 kw/m^2 (0.04 hp/ft^2) for ultrasonic cleaning. The cost of electrical power was assumed at 1.5¢/kw-hr. Other annual maintenance material costs for the strainer were estimated at one percent of the capital cost per year.

Manpower requirements for dynamic straining in an integrated facility were difficult to estimate. Without automation, to optimize effluent quality, the strainer rotational speed would have to be manually changed in response to variations in flow. For this reason, manpower requirements for dynamic straining were conservatively estimated to be 50 percent greater than the manpower requirements for secondary gravity clarifiers in a conventional plant with the same flow rate.

Peak daily flow rates of 6,435 m^3/day (1.7 mgd) and 56,775 m^3/day (15 mgd) were assumed for the 3,785 m^3/day (1 mgd) and 37,850 m^3/day (10 mgd) plants, respectively. For a peak daily flow rate of 6,435 m^3/day (1.7 mgd), fabric area requirements are 13.0 m^2 (140 ft^2, i.e. two strainers) for primary straining and 6.5 m^2 (70 ft^2, i.e. one strainer) for secondary straining. The fabric area requirements for a peak daily flow rate of 56,775 m^3/day (15 mgd) are 117 m^2 (1260 ft^2, i.e. 18 strainers) for primary straining and 58.5 m^2 (630 ft^2 i. e. nine strainers) for secondary straining. These area requirements are equivalent to throughput rates of roughly 7.1 l/sec/m^2 (10.5 gpm/ft^2) for primary straining (includes 25 percent recycle flow from the secondary strainer holding tank) and 11.4 l/sec/m^2 (16.8 gpm/ft^2) for secondary

straining at the peak daily flow rates. To prevent deterioration of effluent quality in the event of strainer breakdown or during maintenance periods, for estimating purposes, one standby strainer was provided for the smaller plant (yielding a total of four strainers) and four standby strainers were provided for the larger plant (yielding a total of 31 strainers). This design requires a return flow rate of 25 percent from the secondary strainer holding tank to the aeration tank.

For the conventional systems using secondary gravity clarification, a design surface loading at average daily flow of 26.5 $m^3/day/m^2$ (650 gpd/ft^2) was utilized for the 3,785 m^3/day (1 mgd) plant and 28.5 $m^3/day/m^2$ (700 gpd/ft^2) was used for the 37,850 m^3/day (10 mgd) plant. The slightly higher average surface loading for the larger plant was allowed because of its smaller peak daily/average daily flow ratio. In addition, for estimating purposes, an excess capacity factor (ECF) of 1.5 was used for secondary clarification for the smaller plant and 1.17 for the larger plant.

A design surface loading for primary clarification at average daily flow of 36.7 $m^3/day/m^2$ (900 gpd/ft^2) was utilized for the 3,785 m^3/day (1 mgd) plants and 40.7 $m^3/day/m^2$ (1,000 gpd/ft^2) was used for the 37,850 m^3/day (10 mgd) plants. Again, the higher average surface loading for the larger plant was selected because of its smaller peak daily/average daily flow ratio. Identical ECF's were used for estimating primary clarification construction costs as were used for secondary clarification.

Raw wastewater characteristics were assumed to be 200 mg/l of BOD_5 and 250 mg/l of suspended solids, Removals during primary clarification were projected to be 35 percent for BOD_5 and 50 percent for suspended solids. Final effluent quality was based on assumed overall removals of 90 percent for both constituents, yielding a BOD_5 of 20 mg/l and a suspended solids of 25 mg/l.

MLSS design levels were established at 2,600 mg/l for the conventional process and 5,500 mg/l for dynamic straining, permitting a 60 percent reduction in aeration tank volume requirements for the dynamic straining plants. For the smaller plants, nominal aeration detention times based on raw wastewater flow of 6.75 and 2.7 hr were selected. respectively, for the conventional and dynamic straining systems. For the larger plants, slightly lower aeration detention times of 6.0 and 2.4 hr, respectively, were used. This resulted in organic loadings of 0.25 kg BOD_5 applied/day/kg MLVSS (0.25 lb BOD_5/day/lb MLVSS) for the smaller plants, and 0.29 kg BOD_5 applied/day/kg MLVSS (0.29 lb BOD_5/day/lb MLVSS) for the larger plants, assuming a 70 percent mixed liquor VSS content. Because the organic loadings were the same for the conventional and dynamic straining plants, waste activated sludge production was assumed to be equal for both systems. For the smaller plants, with a slightly lower organic loading than the larger plants, a waste

activated sludge yield of 0.50 kg VSS/kg BOD_5 removed (0.50 lb VSS/lb BOD_5 removed) was used. A waste activated sludge yield of 0.56 kg VSS/kg BOD_5 removed (0.56 lb VSS/lb BOD_5 removed) was used for the larger plants. In all cases, the VSS content of the waste activated sludge was assumed to be 70 percent.

For estimating aeration tank construction costs, an ECF of 1.5 was used for the 3,785 m^3/day (1 mgd) plants and 1.14 was used for the 37,850 m^3/day (10 mgd) plants. The installed aeration requirements for both processes were assumed to be 110 m^3 air/kg BOD_5 removed (1,770 ft^3 air/lb BOD_5 removed).

The sludge handling and disposal schemes for the two different size plants are discussed below. For both size plants, it was assumed that excess activated sludge was returned to the primary clarifier for joint settling and partial thickening with the primary sludge. The conventional plant excess activated sludge was wasted from the secondary clarifier underflow at a concentration of 13,000 mg/l. The dynamic straining process requires wasting of excess sludge directly from the aeration tank at the assumed MLSS concentration of 6,500 mg/l. Because of the difference in these concentrations, it was assumed that the combined primary and waste activated sludges would thicken to 3.5 percent solids in the primary clarification system of the conventional plants, but only to 3.0 percent solids in the primary clarifiers of the dynamic straining plants.

The combined sludges were further thickened in gravity thickeners. An output of 6.0 percent solids was set as the thickened sludge objective for both types of plants. To achieve this, a solids loading of 39 kg/m^2/day (8 lb/ft^2/day) was utilized to calculate required thickener surface area for the conventional plants with their input combined sludge concentration of 3.5 percent solids. For the thinner 3.0 percent solids input combined sludges produced by the dynamic strainer plants, the thickener design solids loadings were decreased to 31.7 kg/m^2/day (6.5 lb/ft^2/day). ECF's of 2.0 and 1.5 were used, respectively, for estimating thickener construction costs for the smaller and larger plants. The percentage differential in the thickener costs due to the difference in required thickener sizes was much more significant for the 37,850 m^3/day (10 mgd) plants than the 3,785 m^3/day (1 mgd) plants.

As the thickeners were designed to discharge combined primary and waste activated sludges with the same solids content, and since the activated sludge systems were designed to yield identical sludge production, both unit mass and unit volume of the sludges leaving the thickeners were the same for the conventional and dynamic strainer plants. Assuming that the characteristics of these sludges would be very similar, all subsequent sludge handling units were equally sized for the two types of plants.

The thickened sludges were stabilized in each plant in a two-stage

anaerobic digester. A total hydraulic retention time (HRT) of 30 days was assumed, divided equally between the completely mixed first-stage digester and the stratified secondary digester. For estimating digester construction costs, ECF's of 1.5 and 1.33 were used, respectively, for the smaller and larger plants. A VSS reduction of 50 percent during digestion was assumed for all cases.

Dewatering of digested sludge in the smaller plants was accomplished on sludge drying beds. For the larger plants, vacuum filtration of digested sludge was assumed as the dewatering step. Sludge drying bed area was calculated using a digested sludge solids loading of 73 kg/m^2/month (15 lb/ft^2/month). Vacuum filter design was based on a digested sludge solids loading of 19.5 kg/m^2/hr (4 lb/ft^2/hr). ECF's of 1.0 and 1.06 were selected, respectively, for the drying beds and vacuum filters.

Tables 5, 6, and 7 show the estimated total construction costs and the annual operation and maintenance costs for the four plants. Table 8 summarizes these results into total annual costs based on an amortization rate of 7 percent over 20 years. The construction cost for the 3,785 m^3/day (1 mgd) dynamic straining plant was estimated to be 8.2 percent higher than for the conventional plant, while the 37,850 m^3/day (10 mgd) dynamic straining plant would cost about 21.5 percent more initially. Comparing total annual costs, the dynamic straining plants were estimated to cost approximately 8.6 and 23.4 percent more, respectively, than their conventional counterparts. The biggest influence on the larger percent difference in the total annual costs for the 37,850 m^3/day (10 mgd) plants is that the same strainer unit cost was assumed for both size plants, while the cost per ft^2 of surface area for secondary gravity clarification decreased by 50 percent as the size of the plant increased from 3,785 to 37,850 m^3/day (1 to 10 mgd). As stated earlier, larger strainer production units and equipment designed for the process application should substantially decrease cost. However, it would be difficult to assume that a reduction of 50 percent in the cost of straining equipment could be accomplished. For this reason, dynamic straining is more economically feasible for smaller plants.

Safety factors in case of power failure or strainer breakdown are important operational considerations. An emergency auxiliary power source would be one solution to power failure. Flow through the strainers would stop in a very short time during a power failure. This would result in loss of mixed liquor solids to the receiving water unless emergency power was started almost immediately.

If standby strainers were not provided, in the event of strainer breakdown or fabric failure, that unit would have to be shut down, and the specific flow rate through the other strainers would have to be increased by increasing the rotational speed. The 3,785 m^3/day (1 mgd) plant would, as stated previously, require three operating strainers, two primary strainers in the aeration tank and one secondary strainer.

TABLE 5

ESTIMATED TOTAL CONSTRUCTION COSTS

Cost Component		3,785 m^3/day (1 MGD) Conventional Plant		Dynamic Straining Plant
Raw Wastewater Pumping		$ 93,700		$ *
Grit Removal, Flow Measurement, Screening		45,900		*
Primary Sedimentation		65,000		*
Primary Sludge Pumping		37,300		*
Aeration Basin Structure		95,900		51,500
Aeration Diffused Air System		86,500		*
Final Sedimentation		76,400	(Straining)	239,400
Recirculation or Intermediate Pumping		41,200		20,600
Chlorination Feed Systems		32,500		*
Chlorination Contact Basins		15,400		*
Gravity Sludge Thickener		39,500		41,100
Anaerobic Sludge Digestion		181,200		*
Sludge Drying Beds		44,500		*
Administration and Lab Facilities		43,000		*
Garage and Shop Facilities		12,500		*
	Subtotal	$ 910,500		$1,010,100
Yardwork		127,500		*
Total Construction Cost		$1,038,000		1,137,600
Land		11,100		8,900
Engineering		121,300		*
	Subtotal	$1,170,400		$1,267,800
Legal, Fiscal and Administrative		16,200		*
	Subtotal	$1,186,600		$1,284,000
Interest During Construction		72,700		78,700
Total Initial Investment Cost		$1,259,300		$1,362,700

*Same Cost as Conventional Plant.

Note: Estimated Costs Based on National Average EPA-STP Construction Cost Index as of March, 1974 = 190.97.

TABLE 5 (CONTINUED)

ESTIMATED TOTAL CONSTRUCTION COSTS

Cost Component		37,850 m^3/day (10 MGD) Conventional Plant		Dynamic Straining Plant
Raw Wastewater Pumping		$ 456,500		$ *
Grit Removal, Flow Measurement, Screening		176,600		*
Primary Sedimentation		211,500		*
Primary Sludge Pumping		76,600		*
Aeration Basin Structure		458,800		207,900
Aeration Diffused Air System		433,000		*
Final Sedimentation		275,100	(Straining)	1,627,200
Recirculation or Intermediate Pumping		149,500		59,800
Chlorination Feed Systems		86,800		*
Chlorination Contact Basins		52,700		*
Gravity Sludge Thickener		94,500		104,500
Anaerobic Sludge Digestion		464,000		*
Sludge Holding Tanks		77,700		*
Vacuum Filtration		573,700		*
Administration and Lab Facilities		140,600		*
Garage and Shop Facilities		41,600		*
	Subtotal	$ 3,769,200		$4,790,700
Yardwork		527,700		*
Total Construction Cost		$ 4,296,900		$5,318,400
Land		20,000		16,000
Engineering		371,900		*
	Subtotal	$ 4,688,800		$5,706,300
Legal, Fiscal and Administrative		34,500		*
	Subtotal	$ 4,723,300		$5,740,800
Interest During Construction		428,300		520,600
Total Initial Investment Cost		$ 5,151,600		$6,261,400

*Same Cost as Conventional Plant.

Note: Estimated Costs Based on National Average EPA-STP Construction Cost Index as of March, 1974 = 190.97.

TABLE 6

ESTIMATED ANNUAL OPERATION AND MAINTENANCE COSTS

Cost Component	3,785 m^3/day (1 MGD) Plant						
	Conventional Plant				Dynamic Straining Plant		
	Labor	Materials	Total		Labor	Materials	Total
Raw Wastewater Pumping	$ 4,300	$ 1,600	$ 5,900		$ *	$ *	$ *
Grit Removal, Flow Measurement, Screening	4,700	1,800	6,500		*	*	*
Primary Sedimentation	2,800	400	3,200		*	*	*
Primary Sludge Pumping	4,800	1,200	6,000		*	*	*
Aeration Diffused Air System	7,700	9,700	17,400		*	*	*
Final Sedimentation	3,100	500	3,600	(Straining)	4,700	9,900	14,600
Recirculation or Intermediate Pumping	4,100	1,600	5,700		2,100	800	2,900
Chlorination Feed Systems	2,100	4,000	6,100		*	*	*
Gravity Sludge Thickener	2,700	300	3,000		2,900	400	3,300
Anaerobic Sludge Digestion	6,100	1,900	8,000		*	*	*
Sludge Drying Beds	4,900	400	5,300		*	*	*
Administration and Lab Facilities	2,300	1,800	4,100		*	*	*
Laboratory Operation	13,900	500	14,400		*	*	*
Yardwork	3,500	500	4,000		*	*	*
Totals	$ 67,000	$ 26,200	$ 93,200		$66,800	$34,900	$101,700

*Same Cost as Conventional Plant.

Note: Materials Costs include Supplies and Power. Costs based on National Average Wholesale Price Index for Industrial Commodities, March, 1974 = 146.6.
Labor Costs based on Average Labor Cost of $10,400/man-year(U. S. Department of Labor Cost Index of $4.35/hr for March, 1974 plus 15% for Indirect Costs).

TABLE 7

ESTIMATED ANNUAL OPERATION AND MAINTENANCE COSTS

Cost Component	37,850 m^3/day (10 MGD) Plant					
	Conventional Plant			Dynamic Straining Plant		
	Labor	Materials	Total	Labor	Materials	Total
Raw Wastewater Pumping	$ 6,700	$ 8,700	$ 15,400	$ *	$ *	$ *
Grit Removal, Flow Measurement, Screening	15,000	3,900	18,900	*	*	*
Primary Sedimentation	7,700	2,100	9,800	*	*	*
Primary Sludge Pumping	9,500	3,400	12,900	*	*	*
Aeration Diffused Air System	23,000	51,500	74,500	*	*	*
Final Sedimentation	9,600	2,800	12,400	(Straining) $ 14,400	$ 88,600	$ 103,000
Recirculation or Intermediate Pumping	5,800	8,700	14,500	2,300	3,500	5,800
Chlorination Feed Systems	7,800	20,400	28,200	*	*	*
Gravity Sludge Thickener	3,500	700	4,200	3,800	800	4,600
Anaerobic Sludge Digestion	10,700	4,400	15,100	*	*	*
Sludge Holding Tanks	4,500	1,500	6,000	*	*	*
Vacuum Filtration	23,300	26,500	49,800	*	*	*
Administration and Lab Facilities	13,100	5,800	18,900	*	*	*
Laboratory Operation	19,500	2,100	21,600	*	*	*
Yardwork	9,400	2,300	11,700	*	*	*
Totals	$ 169,100	$ 144,800	$ 313,900	$ 170,700	$ 225,500	$ 396,200

*Same Cost as Conventional Plant.

Refer to Table 6 for Costing Basis.

TABLE 8

TOTAL ANNUAL COST COMPARISONS BETWEEN
DYNAMIC STRAINING AND CONVENTIONAL ACTIVATED
SLUDGE TREATMENT PLANTS

	3,785 m^3/day (1 MGD)		37,850 m^3/day (10 MGD)	
	Conventional	Straining	Conventional	Straining
Amortization (7 percent over 20 years)	$ 118,900	$ 128,600	$ 486,300	$ 591,000
Operation and Maintenance	93,200	101,700	313,900	396,200
Totals	$ 212,100	$ 230,300	$ 800,200	$ 987,200
Cost/1000 gal. Treated	58¢	63¢	22¢	27¢
Cost/m^3 Treated	15.3¢	16.6¢	5.8¢	7.1¢

If the secondary strainer failed, the final effluent would temporarily come from the primary strainers. In this case, the suspended solids in the effluent would rise to 30 to 80 mg/l, depending on the momentary specific flow rate while the secondary strainer was not in operation. If a primary strainer failed, a portion of the mixed liquor could be temporarily pumped to the secondary straining tank. This would, in effect, convert the secondary strainer to a primary strainer for the period one of the primary strainers was not operating. The final effluent in this situation would again come from primary strainers. Larger plants with more strainers could handle this transition more successfully and achieve a cleaner final effluent. However, to avoid the situation where effluent quality deteriorates temporarily while one or more of the operating strainers are out of service, the above operational mode was rejected for estimating purposes in favor of providing standby strainer units.

The economics of dynamic straining could be changed by replacing the secondary strainer with a granular-media filter or a gravitational clarifier. Addition of chemicals may be necessary to enhance solids flocculation for gravitational clarification of primary strainer effluent.

A 3,785 m^3/day (1 mgd) sand filter would cost slightly less than a secondary strainer, and the return flow requirements would be about 1/5 as much as secondary straining return flow requirements. The sand filter would, however, not be able to operate as a standby clarification unit in case of a primary strainer breakdown.

Plant upgrading is also a viable application for primary straining. Higher MLVSS levels and reduced solids loadings on existing secondary clarifiers could provide for increased organic and/or hydraulic capacities at minimum investment for plants whose alternative is to expand to treat projected increases in flow. For existing activated sludge plants that are experiencing substantial overloading, primary straining may offer a method of substantially improving overall performance during the interim period before the next planned expansion. In these instances, pure oxygen gas could be used to satisfy the higher oxygen demand created by the higher MLVSS concentrations.

The cost disadvantages of dynamic straining can be offset by several factors. These include positive solids control, especially in locations or applications where filamentous growth is prevalent. Also, total plant land requirements are 20 to 30 percent less with dynamic straining than conventional systems. In urban areas or for expansion purposes, this may be a very important factor. For estimating purposes, a 20 percent reduction in land requirements was used for the dynamic straining plants.

Another potential application for the strainer is as an independent first-stage clarification device in a two-stage activated sludge system.

Two-stage activated sludge systems are being used increasingly where year-round nitrification is required. In these types of systems, it is not necessary for the first-stage clarification unit to achieve very low effluent suspended solids. Rather, it has been found desirable to bleed 35-50 mg/l of BOD_5 and suspended solids into the second-stage nitrification reactor to enhance agglomeration and settling of this essentially autotrophic sludge culture. Primary strainers operating in the first-stage reactor could be tailored to produce an effluent with the desired suspended solids level, and would obviate the need for constructing intermediate first-stage gravity clarifiers. This could be particularly advantageous in converting existing single-stage activated sludge systems to two-stage processes.

SECTION VIII

ACKNOWLEDGEMENTS

The support of the project by the National Environmental Research Center, Office of Research and Development, U. S. Environmental Protection Agency, Cincinnati, Ohio, and the assistance of the Project Officer, Mr. Richard C. Brenner, especially in compilation of the economics data, is acknowledged with sincere thanks.

SECTION IX

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SECTION X

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A. PEAK SPECIFIC FLOW RATES AND SUSPENDED SOLIDS REMOVALS VERSUS DRUM PERIPHERAL VELOCITY

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FIGURE 3 PRIMARY STRAINER, 40-MICRON 54

FIGURE 4 SECONDARY STRAINER, 5-MICRON. 55

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MLSS 6,500 MG/L

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MLSS 9,000 MG/L

TABLE 3 PRIMARY STRAINER, 10-MICRON, ... 59
MLSS 12,000 MG/L

TABLE 4 PRIMARY STRAINER, 20-MICRON, ... 60
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TABLE 5 MARCH 1973 PERFORMANCE DATA 72

TABLE 6 MARCH 1973 OPERATING DATA 73

TABLE 7 APRIL 1973 PERFORMANCE DATA 74

TABLE 8 APRIL 1973 OPERATING DATA 75

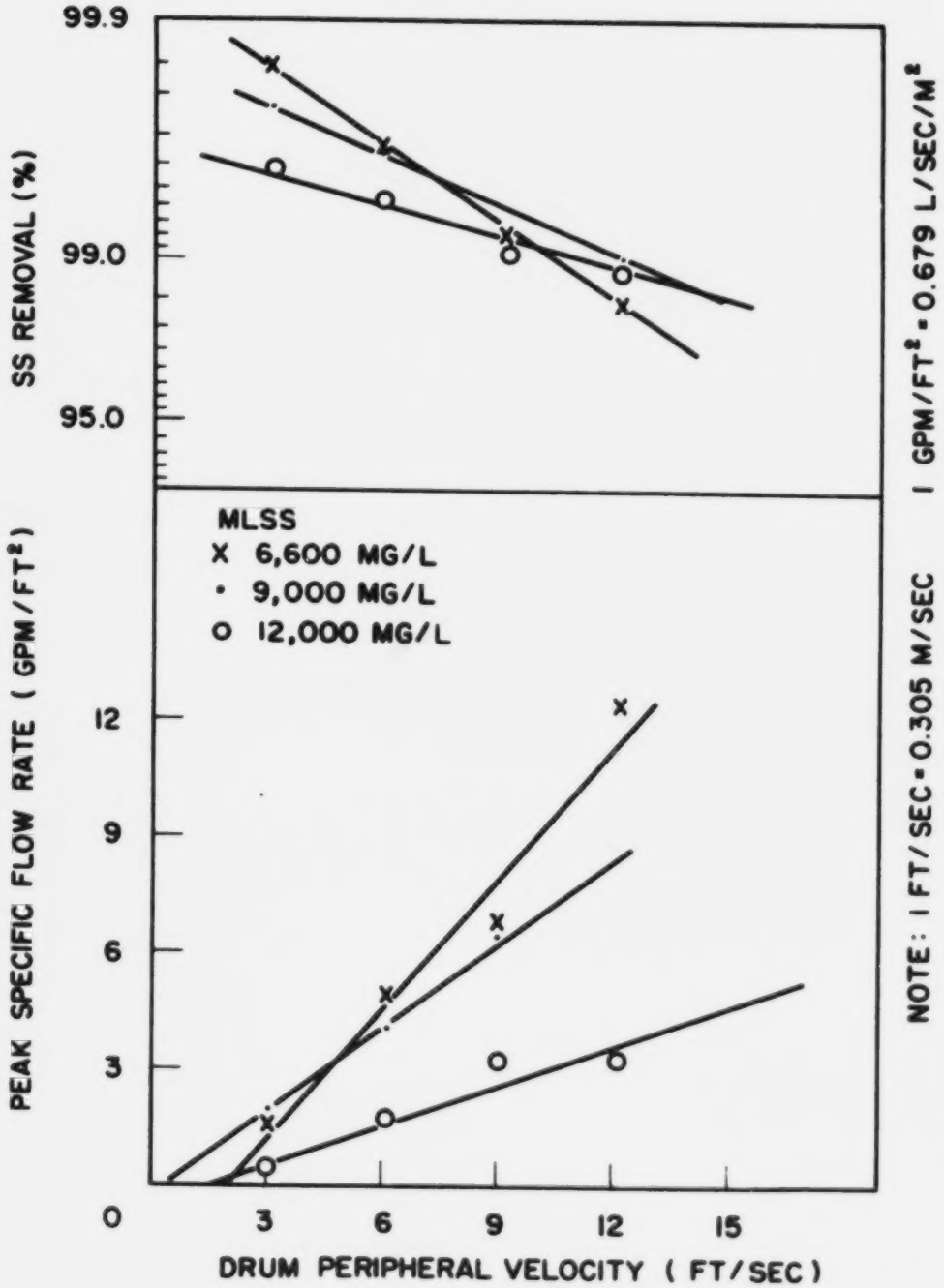

FIGURE A-1

PRIMARY STRAINER, 10-MICRON

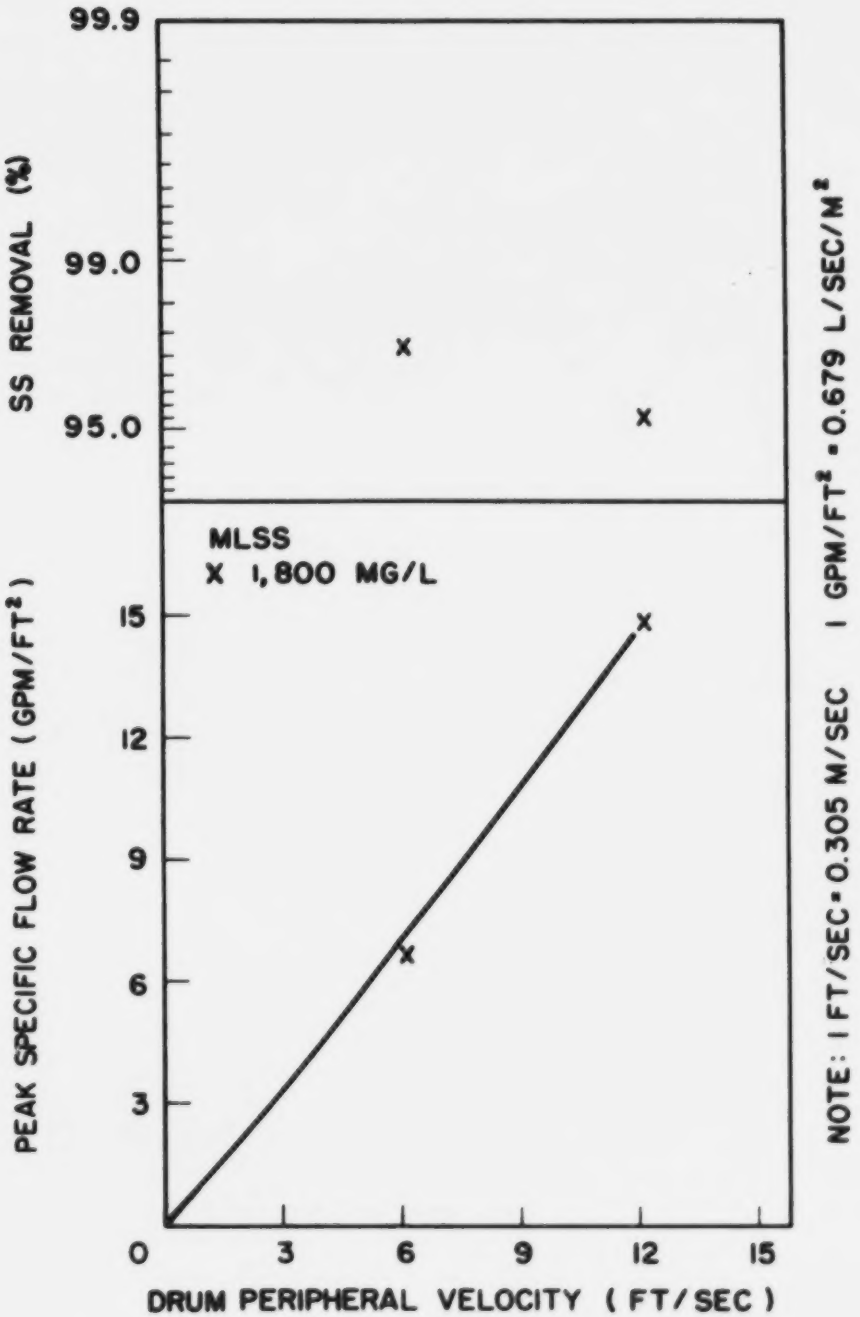

FIGURE A-2
PRIMARY STRAINER, 20-MICRON

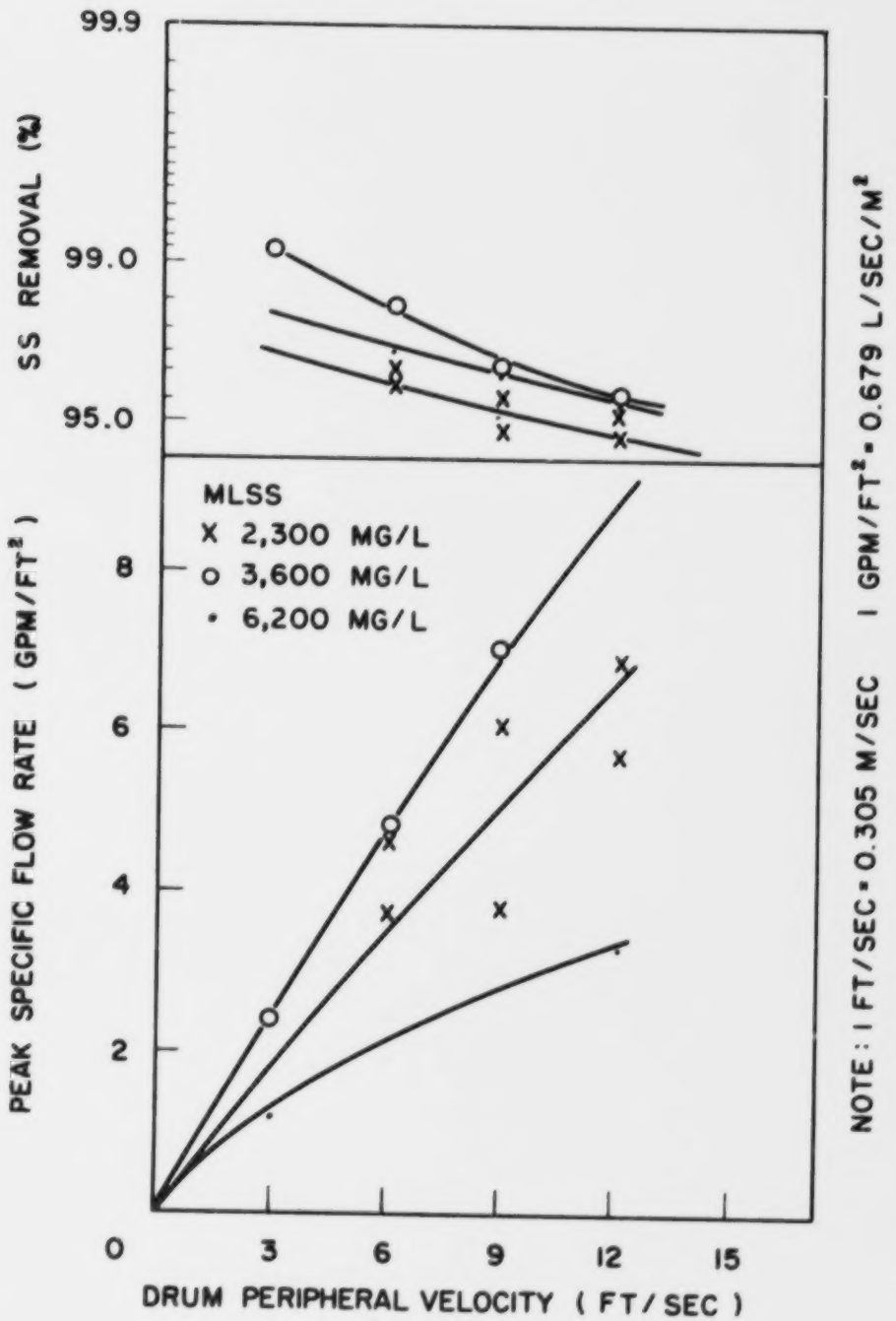

FIGURE A-3
PRIMARY STRAINER, 40-MICRON

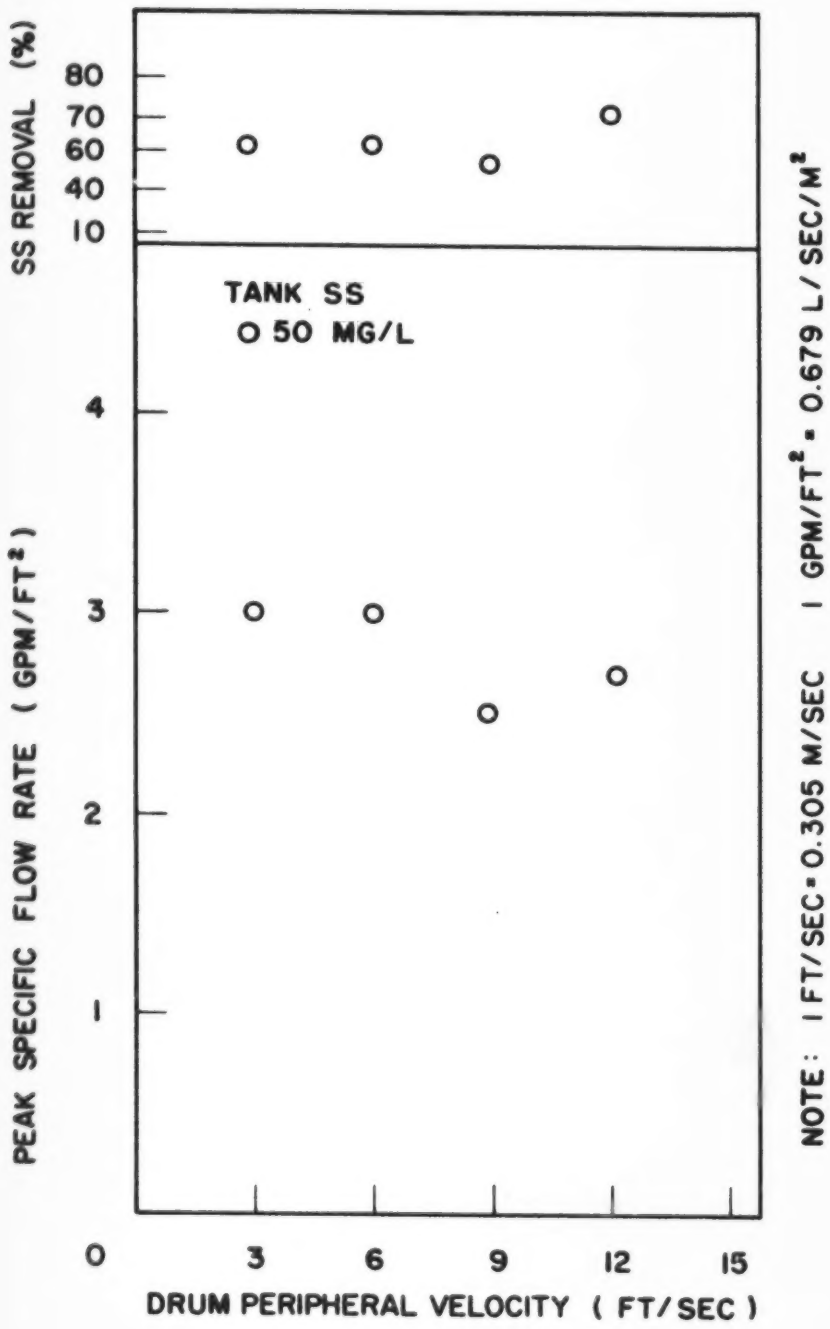

FIGURE A-4

SECONDARY STRAINER, 5-MICRON

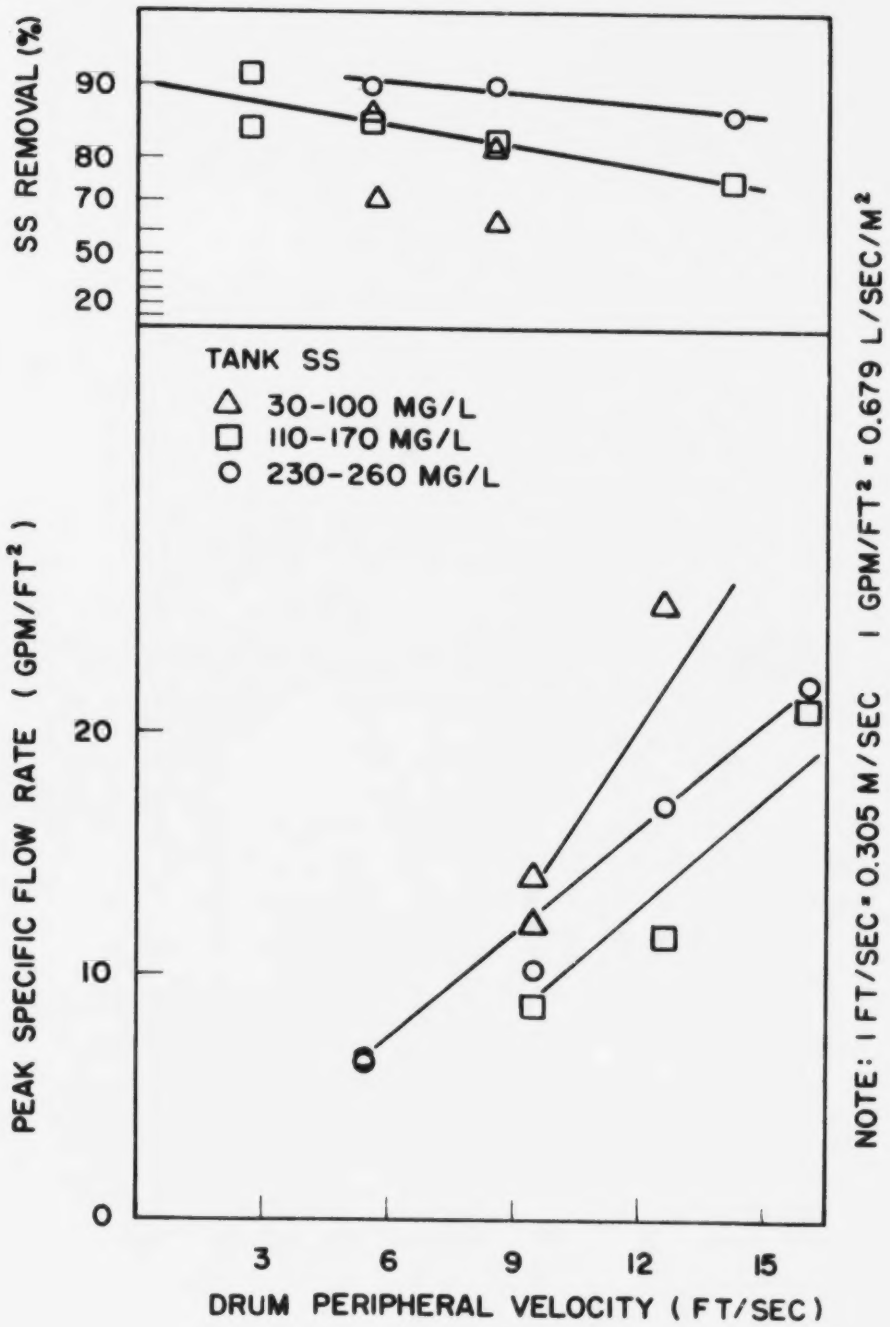

FIGURE A-5
SECONDARY STRAINER, 10-MICRON

TABLE B-1

PRIMARY STRAINER
10-MICRON, MLSS 6,500 MG/L

30 RPM				60 RPM				90 RPM				120 RPM				150 RPM			
Total Head In	Net Head In	Spec. Flow GPM/Ft^2	Eff. SS MG/L	Total Head In	Net Head In	Spec. Flow GPM/Ft^2	Eff. SS MG/L	Total Head In	Net Head In	Spec. Flow GPM/Ft^2	Eff. SS MG/L	Total Head In	Net Head In	Spec. Flow GPM/Ft^2	Eff. SS MG/L	Total Head In	Net Head In	Spec. Flow GPM/Ft^2	Eff. SS MG/L
0.6	0.0	0.0		1.9	0.0	0.0		4.0	0.0	0.0		7.6	0.0	0.0		11.6	0.0	0.0	
1.0	0.4	0.6		2.0	0.1	0.8		4.5	0.5	1.7	57	7.8	0.1	0.8		11.8	0.1	1.0	595
1.1	0.5	1.2		2.1	0.2	1.5	25	4.5	0.5	2.1		7.8	0.1	1.8		11.9	0.2	1.6	
1.2	0.6	1.3		2.4	0.5	2.4		4.8	0.8	2.5	43	8.0	0.4	2.2	97	12.1	0.5	2.1	
1.5	0.9	1.5	12	2.6	0.8	2.8	25	5.0	1.0	2.8		8.5	0.9	3.3		12.4	0.8	2.5	
1.6	1.0	1.6		2.8	0.9	2.7		5.0	1.0	2.9		8.8	1.1	3.9	94	12.6	1.0	2.8	
1.8	1.1	1.6		2.8	0.9	2.9		5.0	1.0	3.2	36	9.0	1.4	5.1		13.4	1.8	3.5	312
1.8	1.1	1.7	13	2.9	1.0	3.0	28	5.2	1.2	3.5		9.2	1.6	5.8	96	13.6	2.0	3.9	
1.9	1.2	1.6		2.9	1.0	3.1		5.4	1.4	4.2		9.2	1.6	6.6		14.1	2.5	4.7	
2.0	1.4	1.6		3.0	1.1	3.3	25	5.6	1.6	4.4	44	10.0	2.4	7.4		14.2	2.6	5.1	
2.1	1.5	1.6		3.0	1.1	3.7		5.8	1.8	4.8	80	10.2	2.6	7.8	116	14.4	2.8	5.5	
2.4	1.8	1.5		3.0	1.1	4.2	17	6.0	2.0	5.1		10.4	2.8	8.8		14.5	2.9	5.1	196
				3.1	1.2	4.4		6.2	2.2	5.5		10.8	3.1	9.4		15.5	3.9	6.1	
				3.1	1.2	4.2		6.5	2.5	6.1	101	10.9	3.2	10.2		15.8	4.1	6.7	
				3.5	1.6	4.4		6.6	2.6	6.7		11.2	3.6	11.0	98	15.9	4.2	6.7	
				3.8	1.9	4.8		7.0	3.0	6.7		11.5	3.9	11.0		16.6	5.0	6.7	
				4.0	2.1	4.4		7.4	3.4	6.1		11.5	3.9	10.2					
				4.2	2.4	4.8		7.6	3.6	5.5		11.6	4.0	11.0					
				4.2	2.4	4.4		8.2	4.2	4.8		12.0	4.4	12.0					
				4.2	2.4	4.2						12.1	4.5	12.0					
				4.5	2.6	3.9						12.6	5.0	11.0					
				4.6	2.8	3.9						13.1	5.5	10.2					
												13.5	5.9	9.4					

MLSS 6,240-6,840 mg/l
Effective Straining Area-4.8 ft^2

TABLE B-2

PRIMARY STRAINER
10-MICRON, MLSS 9,000 MG/L

30 RPM				60 RPM				90 RPM				120 RPM			
Total Head In	Net Head In	Spec. Flow GPM/Ft^2	Eff. SS MG/L	Total Head In	Net Head In	Spec. Flow GPM/Ft^2	Eff. SS MG/L	Total Head In	Net Head In	Spec. Flow GPM/Ft^2	Eff. SS MG/L	Total Head In	Net Head In	Spec. Flow GPM/Ft^2	Eff. SS MG/L
0.6	0.0	0.0		2.0	0.0	0.0		4.0	0.0	0.0		7.4	0.0	0.0	
0.8	0.1	0.5		2.2	0.2	1.0		4.1	0.1	1.0		7.6	0.2	0.9	
0.9	0.2	1.2	24	2.6	0.6	1.6	35	4.5	0.5	1.7	51	7.9	0.5	1.8	91
1.0	0.4	1.5		2.8	0.8	2.1		4.9	0.9	2.6	51	8.0	0.6	2.5	
1.2	0.6	1.7	20	2.8	0.8	2.3	28	5.0	1.0	3.0		8.1	0.8	2.8	81
1.4	0.8	1.7		2.8	0.8	2.4		5.1	1.1	3.5	51	8.4	1.0	3.5	
1.5	0.9	1.9		2.9	0.9	2.7		5.6	1.6	4.5	53	8.5	1.1	3.9	92
1.5	0.9	1.8		2.9	0.9	2.9	31	5.9	1.9	4.8	53	8.5	1.1	4.4	
1.6	1.0	1.8		2.9	0.9	3.0		6.0	2.0	4.9		8.9	1.5	5.1	86
1.8	1.1	1.8		3.0	1.0	3.2		6.0	2.0	5.1		9.2	1.9	5.6	
2.0	1.4	1.7		3.2	1.2	3.5	32	6.2	2.2	5.3	66	9.6	2.2	6.7	96
2.2	1.6	1.7		3.4	1.4	3.9		6.4	2.4	5.6		10.1	2.8	7.4	
				3.5	1.5	3.9		6.4	2.4	5.7		10.4	3.0	7.4	
				3.6	1.6	3.9		5.8	2.8	6.1		10.8	3.4	7.9	
				4.0	2.0	3.9	36	6.8	2.8	6.3	79	11.0	3.6	7.9	
				4.2	2.2	4.0		6.9	2.9	6.1		11.2	3.9	7.4	
				4.2	2.2	4.0		7.0	3.0	6.3		11.8	4.4	7.9	88
				4.2	2.2	3.8		7.0	3.0	6.3		12.5	5.1	6.7	
				4.2	2.5	3.5		7.1	3.1	6.1		12.8	5.4	6.1	
								7.8	3.8	6.1		12.9	5.5	5.8	
								8.2	4.2	5.5					
								8.5	4.5	5.1					
								6.4	4.8	4.7					

MLSS 8,760-9,540 mg/l
Effective Straining Area-4.8 ft^2

TABLE B-3

PRIMARY STRAINER
10-MICRON, MLSS 12,000 MG/L

30 RPM				60 RPM				90 RPM				120 RPM			
Total Head In	Net Head In	Spec. Flow GPM/Ft^2	Eff. SS MG/L	Total Head In	Net Head In	Spec. Flow GPM/Ft^2	Eff. SS MG/L	Total Head In	Net Head In	Spec. Flow GPM/Ft^2	Eff. SS MG/L	Total Head In	Net Head In	Spec. Flow GPM/Ft^2	Eff. SS MG/L
1.1	0.0	0.0		2.9	0.0	0.0		5.0	0.0	0.0		8.2	0.0	0.0	
1.5	0.4	0.4		3.0	0.1	0.5		5.5	0.5	0.7		8.6	0.4	0.7	
1.8	0.6	0.5	53	3.2	0.4	1.0		5.9	0.9	1.4		9.1	0.9	1.4	
2.4	1.2	0.5		3.4	0.5	1.1	65	6.0	1.0	1.7	99	9.2	1.0	1.9	154
3.1	2.0	0.5		3.6	0.8	1.2		6.1	1.1	2.1		9.4	1.1	2.1	
				3.8	0.9	1.4		6.4	1.4	2.1		9.6	1.4	2.3	
				3.9	1.0	1.6	72	6.6	1.6	2.3	92	9.8	1.5	2.5	
				4.0	1.1	1.7		6.8	1.8	2.5		10.0	1.8	2.6	
				4.1	1.2	1.8		6.9	1.9	2.6		10.0	1.8	2.7	
				4.2	1.4	1.8		6.9	1.9	2.7		10.1	1.9	2.8	124
				4.2	1.4	1.8		6.9	1.9	2.7		10.1	1.9	3.0	
				4.5	1.6	1.8		6.9	1.9	2.8		10.2	2.0	3.2	
				4.6	1.8	1.8		7.0	2.0	2.9	88	10.4	2.1	3.0	
				4.9	2.0	1.7		7.1	2.1	2.9		10.6	2.4	2.9	
				5.0	2.1	1.7		7.2	2.2	3.0		10.8	2.5	2.8	
				5.1	2.2	1.7		7.2	2.2	3.0		11.0	2.4	2.8	
				5.2	2.4	1.7		7.5	2.5	3.2					
								7.8	2.8	3.2					
								8.0	3.0	3.2					
								8.1	3.1	3.0					
								8.2	3.2	2.9					
								8.5	3.5	2.9					

MLSS 11,520-12,720 mg/l
Effective Straining Area-4.8 ft^2

TABLE B-4

PRIMARY STRAINER
20-MICRON, MLSS 1,800 MG/L; 40-MICRON, MLSS 2,300 MG/L

60 RPM				120 RPM				90 RPM				120 RPM			
Total Head In	Net Head In	Spec. Flow GPM/Ft^2	Eff. SS MG/L	Total Head In	Net Head In	Spec. Flow GPM/Ft^2	Eff. SS MG/L	Total Head In	Net Head In	Spec. Flow GPM/Ft^2	Eff. SS MG/L	Total Head In	Net Head In	Spec. Flow GPM/Ft^2	Eff. SS MG/L
2.0	0.0	1.4	49	7.4	0.0	1.2	86	4.9	0.4	0.9		8.9		2.4	119
2.4	0.4	2.5		7.9	0.5	2.2		5.1	0.6	1.8	88	9.0		3.0	124
2.6	0.6	3.4	45	8.2	0.9	2.8		5.1	0.6	2.0		9.1		3.7	
2.9	0.9	4.2		8.2	0.9	3.2		5.4	0.9	2.3		9.4		4.2	128
3.2	1.2	5.4		8.4	1.0	4.1		5.5	1.0	2.4		9.8		5.0	136
3.4	1.4	6.0		8.6	1.2	5.3		5.6	1.1	2.6		10.1		5.5	
3.6	1.6	6.6	38	8.9	1.5	5.9	78	5.8	1.2	2.7		10.9		6.5	
4.0	2.0	6.0		9.1	1.8	7.0		5.8	1.2	2.8	96	11.2		6.9	
4.4	2.4	5.1	42	9.1	1.8	7.8		5.8	1.2	2.8		11.4		6.9	
5.0	3.0	4.0		9.4	2.0	8.9	78	5.8	1.2	3.0		11.9		6.5	
5.6	3.4	3.4	37	9.8	2.4	9.5		5.9	1.4	3.3		12.2		6.9	
				10.2	2.9	11.0	88	6.1	1.6	3.6		12.9		6.5	
				10.5	3.1	12.3		6.2	1.8	3.7		13.0		6.1	
				11.6	4.2	14.7	86	6.4	1.9	3.8		13.5		5.8	
				11.8	4.4	13.2		6.6	2.1	3.8		13.6		5.5	
				12.4	5.0	14.7	76	6.8	2.2	3.7		13.9		5.2	
				13.1	5.8	13.2		6.9	2.4	3.6	84				
				13.4	6.0	12.3		7.1	2.6	3.5					
				13.5	6.1	11.0		7.4	2.9	3.3					
								7.5	3.0	3.2					

MLSS 1,725-1,935 mg/l
Effective Straining Area-4.8 ft^2

MLSS 2,180-2,480 mg/l
Effective Straining Area-2.9 ft^2

TABLE B-5

PRIMARY STRAINER
40-MICRON, MLSS 2,400 MG/L

60 RPM				50 RPM				90 RPM				120 RPM			
Total Head In	Net Head In	Spec. Flow GPM/Ft^2	Eff. SS MG/L	Total Head In	Net Head In	Spec. Flow GPM/Ft^2	Eff. SS MG/L	Total Head In	Net Head In	Spec. Flow GPM/Ft^2	Eff. SS MG/L	Total Head In	Net Head In	Spec. Flow GPM/Ft^2	Eff. SS MG/L
2.6	0.4	2.8		2.4	0.1	1.3	59	4.4	0.1	1.2	172	10.6	0.1	1.1	85
2.8	0.6	3.1	78	2.5	0.2	1.8	67	4.9	0.6	2.7	150	10.9	0.4	2.0	
2.9	0.7	3.1		2.6	0.4	2.1		5.0	0.8	3.1		10.9	0.4	2.4	100
2.9	0.7	3.6		2.9	0.6	2.5		5.1	0.9	3.3		11.4	0.9	3.1	109
2.9	0.7	3.6		3.0	0.8	3.0	71	5.1	0.9	3.7	135	11.6	1.1	3.7	
2.9	0.7	3.5		3.1	0.9	3.3		5.2	1.0	4.0		11.9	1.4	4.1	125
2.9	0.7	3.8		3.1	0.9	3.4	82	5.6	1.4	4.4	139	12.0	1.5	4.6	
3.0	0.8	3.9	79	3.4	1.1	3.7		5.9	1.6	4.6		12.4	1.9	4.8	114
3.1	0.9	4.2		3.8	1.5	3.4	67	5.9	1.6	4.6		12.8	2.2	4.9	
3.1	0.9	4.3		4.1	1.9	3.3		6.1	1.9	4.9	101	12.9	2.4	5.2	
3.2	1.0	4.4	76	4.9	2.6	3.2		6.1	1.9	5.2		13.1	2.6	5.5	
3.4	1.2	4.6		5.2	3.0	3.1	53	6.2	2.0	5.5	109	13.8	3.2	5.5	113
3.5	1.3	4.8						6.4	2.1	6.0		14.1	3.6	5.7	
3.6	1.4	4.6						6.5	2.2	6.0	97	14.4	3.9	5.2	
3.8	1.6	4.4						6.8	2.5	6.1		14.5	4.0	4.8	105
3.9	1.7	4.4						6.9	2.6	6.0		14.6	4.1	4.6	
4.0	1.8	4.3						7.1	2.9	5.8					
4.1	1.9	4.2	120					7.1	2.9	6.0					
								7.2	3.0	5.5	91				
								7.5	3.2	5.0					
								7.8	3.5	4.8					
								8.0	3.8	4.4					

MLSS 2,260-2,520 mg/l
Effective Straining Area-2.9 ft^2

TABLE B-6

PRIMARY STRAINER
40-MICRON, MLSS 6,200 MG/L

30 RPM				60 RPM				90 RPM				120 RPM			
Total Head In	Net Head In	Spec. Flow GPM/Ft^2	Eff. SS MG/L	Total Head In	Net Head In	Spec. Flow GPM/Ft^2	Eff. SS MG/L	Total Head In	Net Head In	Spec. Flow GPM/Ft^2	Eff. SS MG/L	Total Head In	Net Head In	Spec. Flow GPM/Ft^2	Eff. SS MG/L
1.0	0.0	0.0		2.5	0.0	0.0		5.6	0.0	0.0		9.1	0.0	0.0	
1.2	0.2	0.8	420	2.6	0.1	0.9	186	6.1	0.5	0.8	168	9.4	0.2	0.8	316
1.5	0.5	1.2		2.8	0.2	1.5	152	6.4	0.8	1.3	174	9.8	0.6	1.7	327
1.8	0.8	1.2		3.0	0.5	1.8		6.6	1.0	1.5		10.0	0.9	2.1	
2.1	1.1	1.2	320	3.2	0.8	1.9		7.0	1.4	1.5		10.0	0.9	2.0	290
2.4	1.4	1.1		3.4	0.9	2.1	146	7.5	1.9	1.4		10.0	0.9	2.1	
2.6	1.6	1.1		3.4	0.9	2.1		7.9	2.2	1.2		10.0	0.9	2.3	
				3.5	1.0	2.2						10.2	1.1	2.5	278
				3.5	1.0	2.2						10.4	1.2	2.6	
				3.6	1.1	2.3						10.4	1.2	2.6	
				3.8	1.2	2.4	126					10.4	1.2	2.8	
				3.8	1.2	2.3						10.4	1.2	2.8	
				3.8	1.2	2.4						10.5	1.4	2.9	
				3.9	1.4	2.4						10.6	1.5	3.0	240
				3.9	1.4	2.4						10.6	1.5	3.0	
				4.1	1.6	2.3						10.8	1.6	3.0	
				4.4	1.9	2.1						11.0	1.9	3.3	215
				4.6	2.1	2.0						11.5	2.4	3.2	
												11.6	2.5	2.9	
												11.8	2.6	2.8	

MLSS 5,900-6,420 mg/l
Effective Straining Area-4.8 ft^2

TABLE B-7

PRIMARY STRAINER
40-MICRON, MLSS 3,600 MG/L

30 RPM				60 RPM				90 RPM				120 RPM			
Total Head In	Net Head In	Spec. Flow GPM/Ft^2	Eff. SS MG/L	Total Head In	Net Head In	Spec. Flow GPM/Ft^2	Eff. SS MG/L	Total Head In	Net Head In	Spec. Flow GPM/Ft^2	Eff. SS MG/L	Total Head In	Net Head In	Spec. Flow GPM/Ft^2	Eff. SS MG/L
0.9	0.0	0.0		2.5	0.0	0.0		4.6	0.0	0.0		8.2	0.0	0.0	
1.1	0.2	1.0	31	2.8	0.2	0.4		4.8	0.1	1.0	105	8.6	0.4	1.1	
1.2	0.4	1.8		2.9	0.4	1.6	64	5.5	0.9	2.7	107	9.1	0.9	2.4	144
1.4	0.5	2.0	47	3.0	0.5	2.3	65	5.6	1.0	3.7	101	9.2	1.0	3.5	134
1.4	0.5	2.2		3.2	0.8	2.7		5.8	1.1	3.9		9.6	1.4	3.9	
1.4	0.5	2.4		3.4	0.9	3.0	56	5.9	1.2	4.2		9.9	1.6	4.2	
1.4	0.5	2.3		3.6	1.1	3.5		6.0	1.4	4.4		10.0	1.8	4.7	128
1.4	0.5	2.4	31	3.6	1.1	3.9	57	6.0	1.4	4.4	105	10.1	1.9	5.5	
1.4	0.5	2.4		3.8	1.2	4.2		6.1	1.5	5.1		10.1	1.9	5.1	
1.5	0.6	2.4		3.9	1.4	4.4	53	6.1	1.5	5.1		10.4	2.1	5.5	
1.8	0.9	2.3		3.9	1.4	4.8		6.1	1.5	5.1		10.4	2.1	5.5	127
2.0	1.1	2.1		4.0	1.5	4.4		6.2	1.6	5.5	96	10.5	2.2	6.1	
2.1	1.2	2.1	26	4.0	1.5	4.8		6.4	1.8	5.8		10.6	2.4	6.3	
2.6	1.8	1.9		4.0	1.5	4.8		6.5	1.9	6.1		10.8	2.5	6.7	
				4.0	1.5	4.9		6.6	2.0	6.7		11.0	2.8	7.4	
				4.0	1.5	4.9		6.9	2.2	6.7		11.6	3.4	8.3	
				4.2	1.8	4.8	49	7.2	2.6	7.0		12.2	4.0	8.9	
				4.4	1.9	4.4		7.5	2.9	6.7		12.4	4.1	8.3	
				4.6	2.1	4.2		7.6	3.0	6.1		12.6	4.4	7.4	108
				4.9	2.4	3.9		7.9	3.2	4.8		13.0	4.8	6.7	
				5.0	2.5	3.5		8.4	3.8	3.7		13.2	5.0	5.6	
												13.6	5.4	5.1	

MLSS 3,350-3,800 mg/l
Effective Straining Area-4.8 ft^2

TABLE B-8

SECONDARY STRAINER
5-MICRON, TANK SS 50 MG/L

37 RPM					60 RPM					90 RPM					120 RPM				
Total Head In	Net Head In	Spec. Flow GPM/Ft^2	Eff. SS MG/L	Tank SS MG/L	Total Head In	Net Head In	Spec. Flow GPM/Ft^2	Eff. SS MG/L	Tank SS MG/L	Total Head In	Net Head In	Spec. Flow GPM/Ft^2	Eff. SS MG/L	Tank SS MG/L	Total Head In	Net Head In	Spec. Flow GPM/Ft^2	Eff. SS MG/L	Tank SS MG/L
1.0	0.0	0.0			2.6	0.0	0.0			6.8	0.0	0.0			10.8	0.0	0.0		
1.5	0.5	1.0	18	59	3.2	0.6	1.0	20	54	7.1	0.4	0.9			12.0	1.2	1.3	10	39
2.0	1.0	1.2	19		3.4	0.8	1.6			7.6	0.9	1.7	18	39	12.5	1.6	1.7		
2.8	1.8	1.3	21		4.2	1.6	2.6	14		8.0	1.2	1.7			12.8	2.0	1.8		
3.8	2.8	1.3			6.0	3.4	2.6			8.8	1.6	2.0			13.1	2.4	2.0		
4.8	3.8	1.3	24		6.2	5.6	2.6			9.1	2.4	0.0			13.5	2.8	2.0		
5.8	4.8	1.3			11.0	8.4	2.6	17		10.2	3.5	2.4			14.0	3.2	2.6		
7.2	6.2	1.5	27		14.0	11.4	2.6			10.8	4.0	2.1	18		14.8	4.0	2.8	12	
8.5	7.5	1.9			15.8	13.1	2.7			11.5	4.8	2.1			15.5	4.8	2.6		
9.5	8.5	2.1			17.8	15.1	2.9			12.5	5.8	2.1			16.8	6.0	2.4		
11.0	10.0	2.3	29		19.0	16.4	3.0			13.5	6.8	2.0			18.0	7.2	2.1		
13.2	12.2	2.4			21.2	18.6	3.0	30	51										
15.8	14.8	2.6			22.2	19.6	2.9												
17.5	16.5	2.7			24.2	21.6	2.7												
18.5	17.5	2.9			25.5	22.9	2.7												
20.5	19.5	2.9			26.5	23.9	2.6												
22.5	21.5	3.0																	
24.2	23.2	2.8	43	61															
26.0	25.0	2.5																	

Effective Straining Area-4.8 ft^2

TABLE B-9

SECONDARY STRAINER
10-MICRON, TANK SS 40 MG/L

90 RPM					90 RPM					120 RPM					120 RPM				
Total Head In	Net Head In	Spec. Flow GPM/Ft^2	Eff. SS MG/L	Tank SS MG/L	Total Head In	Net Head In	Spec. Flow GPM/Ft^2	Eff. SS MG/L	Tank SS MG/L	Total Head In	Net Head In	Spec. Flow GPM/Ft^2	Eff. SS MG/L	Tank SS MG/L	Total Head In	Net Head In	Spec. Flow GPM/Ft^2	Eff. SS MG/L	Tank SS MG/L
6.5	0.0	0.0			6.8	0.0	0.0			12.5	0.5	6.1	11	91	12.0	0.0	0.0		
7.0	0.5	6.7	15	20	7.1	0.4	3.5	11	99	13.0	1.0	8.9			12.5	0.5	3.7	19	95
7.9	1.4	11.0			7.5	0.8	7.3			13.4	1.4	11.0	14	29	12.9	0.9	7.6		
8.0	1.5	11.0	14	46	7.9	1.1	9.1	13	97	14.0	2.0	17.5			13.4	1.4	9.5		
8.0	1.5	10.5			9.0	2.2	12.1			14.2	2.2	20.3	13	31	13.6	1.6	13.3		
8.1	1.6	11.5	11	35	9.6	2.9	18.2			14.6	2.6	22.1			14.2	2.2	17.5	18	91
8.4	1.9	13.3			11.0	5.0	7.9	10	89	15.1	3.1	25.4	11	36	14.9	2.9	20.2		
8.6	2.1	13.7			12.2	5.5	7.4			16.5	4.5	25.4			15.2	3.2	21.9		
9.0	2.5	14.1			13.2	6.5	7.1			17.6	5.6	25.0			16.0	4.0	25.2		
9.4	2.9	13.0								18.1	6.1	21.1			16.6	4.6	23.9	16	85
10.0	3.5	11.0								18.8	6.8	18.9			17.8	5.8	21.0		
11.5	5.0	9.4								19.6	7.6	13.3			19.0	7.0	17.9	13	87
13.5	7.0	9.4								22.0	10.0	9.2	9	32	21.0	9.0	16.2		
16.0	9.5	8.9								23.6	11.6	6.6			21.8	9.8	15.6		
18.2	11.8	8.2								25.2	13.2	5.9			23.6	11.6	14.6	11	75
19.4	12.9	7.9													25.4	13.4	14.2		
22.0	15.5	7.3	22	52											26.4	14.4	13.5		
25.2	18.8	6.4																	
28.0	21.1	6.0																	

Effective Straining Area-1.26 ft^2

TABLE B-10

SECONDARY STRAINER
10-MICRON, TANK SS 150 MG/L

60 RPM					90 RPM					120 RPM					180 RPM				
Total Head In	Net Head In	Spec. Flow GPM/Ft^2	Eff. SS MG/L	Tank SS MG/L	Total Head In	Net Head In	Spec. Flow GPM/Ft^2	Eff. SS MG/L	Tank SS MG/L	Total Head In	Net Head In	Spec. Flow GPM/Ft^2	Eff. SS MG/L	Tank SS MG/L	Total Head In	Net Head In	Spec. Flow GPM/Ft^2	Eff. SS MG/L	Tank SS MG/L
2.5	0.0	0.0			6.0	0.0	0.0			11.2	0.0	0.0			22.9		3.3		
3.0	0.5	2.3			6.5	0.5	3.3			11.5	0.2	3.3			23.4		5.8	40	163
3.2	0.8	3.4			6.8	0.8	4.9	27	169	11.8	0.5	4.5	28	165	23.5		7.5		
3.2	0.8	3.6	27	167	6.9	0.9	5.4			12.0	0.8	5.2			23.9		8.7		
3.4	0.9	4.1			7.0	1.0	5.8			12.0	0.8	5.8			24.1		10.2	43	170
3.4	0.9	5.1			7.5	1.5	7.2	22	166	12.4	1.1	7.5	30	167	24.5		11.5		
3.6	1.1	5.6			7.4	1.4	8.2			12.5	1.2	8.5			24.6		12.7		
3.8	1.2	5.8			7.5	1.5	8.2			12.6	1.4	8.7			24.9		13.4	53	162
4.0	1.5	5.5	21	165	7.6	1.6	8.2			12.8	1.5	8.7			25.2		14.9		
4.5	2.0	4.1			7.6	1.6	8.5			12.9	1.6	9.1			25.2		14.1		
					7.8	1.8	8.7			13.0	1.8	9.8			25.4		14.9		
					8.0	2.0	8.7	19	164	13.0	1.8	10.2	28	166	25.4		15.9		
					8.1	2.5	8.7			13.1	1.9	10.2			25.5		15.9		
					8.4	2.4	7.9			13.2	2.0	10.6			25.8		17.0		
					8.6	2.6	7.1			13.5	2.2	10.6			26.0		18.1	31	
										13.6	2.4	10.8			26.4		17.0		
										13.8	2.5	11.0			26.5		18.1		
										14.0	2.8	11.0			27.0		19.5		
										14.1	2.9	11.0			27.4		21.1		
										14.2	3.0	11.6			28.0		21.1		
										14.5	3.2	11.6	25	171	28.2		21.1		
										15.0	3.8	11.0							
										15.2	4.0	9.8							
										15.8	4.5	7.9							

Effective Straining Area-1.26 ft^2

TABLE B-11

SECONDARY STRAINER
10-MICRON, TANK SS 200 MG/L

60 RPM					90 RPM					120 RPM					180 RPM				
Total Head In	Net Head In	Spec. Flow GPM/Ft^2	Eff. SS MG/L	Tank SS MG/L	Total Head In	Net Head In	Spec. Flow GPM/Ft^2	Eff. SS MG/L	Tank SS MG/L	Total Head In	Net Head In	Spec. Flow GPM/Ft^2	Eff. SS MG/L	Tank SS MG/L	Total Head In	Net Head In	Spec. Flow GPM/Ft^2	Eff. SS MG/L	Tank SS MG/L
2.9	0.0	0.0			6.0	0.0	0.0			11.5		6.7	23	256	21.0	0.0	0.0		
3.0	0.1	2.9			7.8	1.8	8.2			11.5		5.8			21.8	0.8	3.2		
3.4	0.5	3.8			1.9	1.9	8.3	21	228	11.6		7.7			22.0	1.0	5.4	41	252
3.5	0.6	4.0			8.1	2.5	8.7			11.9		9.0	30	249	22.5	1.5	8.1		254
3.5	0.6	4.1	9	118	8.2	2.2	9.5			11.9		9.4			22.8	1.8	8.1		
3.5	0.6	4.4			8.4	2.4	10.2			11.9		10.4			23.2	2.2	10.8	19	260
3.6	0.8	5.1			8.5	2.5	10.2	22	226	12.1		10.8			23.5	2.5	11.5		
3.9	1.0	5.6			8.6	2.6	10.2			12.1		11.0			23.8	2.8	13.7		
4.1	1.2	5.6	11	110	9.2	3.2	9.5			12.2		11.5			24.0	3.0	15.4		
4.4	1.5	5.2			9.0	3.0	8.7			12.2		11.8			24.6	3.6	18.1	38	253
4.6	1.8	4.8			9.1	3.1	8.7			12.4		12.4			24.9	3.9	19.5		
5.0	2.1	4.5	9	108	9.2	3.2	8.9			12.5		12.7			25.1	4.1	20.4		
					9.4	3.4	8.5			12.6		13.3			25.5	4.5	21.1		
					9.5	3.5	8.2			12.8		14.1			25.6	4.6	21.1		
										12.8		14.5	62	256	25.8	4.8	22.0		
										13.0		14.9			26.1	5.1	21.1		
										13.1		15.4			26.4	5.4	21.1		
										13.5		17.0			26.6	5.6	21.1		
										13.9		17.0			27.0	6.0	21.1		
										14.2		16.3	26	254	27.8	6.8	21.1		
										14.5		15.9			28.4	7.4	20.4		
										14.9		15.4			28.8	7.8	19.5		
										15.4		14.1			29.0	8.0	19.5		
										15.8		13.0							

Effective Straining Area-1.26 ft^2

TABLE C-1

JANUARY 1973 PERFORMANCE DATA

	PRIMARY EFFLUENT						MIXED LIQUOR		PRIMARY STRAINER EFFLUENT				SECONDARY STRAINER EFFLUENT			
Date	Q gpd x 10^3	TOC/SOC mg/l	BOD/COD mg/l	SS/VSS mg/l	NH_3-N mg/l	pH	SS mg/l	VSS mg/l	BOD/COD mg/l	TOC/SOC mg/l	SS/VSS mg/l	NH_3-N mg/l	BOD/COD mg/l	TOC/SOC mg/l	SS/VSS mg/l	NH_3-N mg/l
1																
2	10	128/73		96/83	21.5	8.1	3360	3050								
4	10	103/63	117/197	69/58	10.8	7.5	3760	3250		21/8	43/37	11.3		23/9	41/37	10.7
5	10	116/75	159/-	125/105	10.8	7.6	4230	3630	23/-	23/9	45/34	7.1	22/-	26/11	37/27	7.1
6	10								30/-	29/12	49/36	9.9	13/-	26/12	40/32	9.9
7	10															
8	10	120/56	168/-	118/100	15.0	7.5	5030	4500	36/-	39/12	71/62	12.5	33/-	37/13	53/46	12.5
9	12	59/39		23/23	7.9	7.3	4420	4000		21/9	-/24	8.8		18/8	-/24	8.1
10	15	99/37	145/-	167/132	10.2	7.5	4620	3970	51/-	28/10	85/67	6.5	27/-	23/12	37/29	5.7
11	17	95/52	-/355	95/70	8.5	7.6	3210	2630		19/7	42/27	5.7	-/62	15/8	27/17	4.5
12	15	116/60	145/-	38/36	11.9	7.3	3710	3350	50/-	34/19	50/46	9.6	48/-	32/17	44/40	9.9
13	11															
14	11															
15	10	62/42	63/-	46/44	18.7	7.7	4340	3820	17/-	33/11	62/54		11/-	33/11	62/54	2.0
16	15	89/52		128/113	11.9	7.8	3560	3260		22/5	64/64	ND(*)		21/6	50/40	ND
17	18	99/44	80/-	99/82	7.4	7.3	3780	3290	34/-	30/10	69/58	ND	31/-	34/10	56/49	ND
18	9															
22	10	184/-		100/-												
23	10													9/-	4/-	
24	10						2230									
25	10	59/-					1710									
26	10						1890							8/-	3/-	
27	10						1920									
28	10															
29	0	120/-		94/-			1900							8/-	4/-	
30	5	60/-		63/-			1925							8/-	4/-	
31	3						1300									

(*) ND = Non Detectable

TABLE C-2

JANUARY 1973 OPERATING DATA

	MIXED LIQUOR		PRIMARY STRAINER		SECONDARY STRAINER		AERATION TANK		
Date	Load Factor Lbs BOD / Lb MLVSS	Wasted Solids Lbs/day	Head in H_2O	Velocity Ft/Min	Head in H_2O	Velocity Ft/Min	Return Flow gpm	Return SS mg/l	Air Flow Lbs/hr
1			1.5	330	10	766	8		70
2			1.5	330	10	760	8		70
3			2.0	330	10	760	8		70
4	0.10		1.5	330	10	760	8		70
5	0.12		1.5	330	10	760	8		70
6							8		
7							8		
8	0.11		2.0	330	10	760	8		70
9	0.15	24.7	2.0	330	9.5	760	9		69
10	0.12	37.5	2.0	330	10	760	9		70
11		17.5	1.5	330	10	760	8		75
12	0.19		1.3	330	10	700	7		71
13							7		
14							7		
15	0.47	32.1	1.3	330	10	685	7		156
16		8.8	1.5	330	10.3	685	8	190	156
17	0.12	6.2	1.5	330		685	4	79	161

Primary Strainer: 20 micron fabric, ultrasonic current 5.7-6.0 amps
Secondary Strainer: 10 micron fabric, ultrasonic current 2.4-3.7 amps

TABLE C-3

FEBRUARY 1973 PERFORMANCE DATA

	PRIMARY EFFLUENT						MIXED LIQUOR		PRIMARY STRAINER EFFLUENT				SECONDARY STRAINER EFFLUENT			
Date	Q gpd x 10^3	TOC/SOC mg/l	BOD/COD mg/l	SS/VSS mg/l	NH_3-N mg/l	pH	SS mg/l	VSS mg/l	BOD/COD mg/l	TOC/SOC mg/l	SS/VSS mg/l	NH_3-N mg/l	BOD/COD mg/l	TOC/SOC mg/l	SS/VSS mg/l	NH_3-N mg/l
1	8	144/65	/500	166/166	26.6	7.3	1365	1125		18/11	13/10	ND (*)	-/23	14/9	3/3	ND
2	11	100/56		116/85	8.5	7.3	1920	1590		15/8	8/6	2.3		14/9	2/2	1.5
3	8															
4	8															
5	9	85/42		52/46	9.9	7.3	2765	2380		19/18	19/14	ND		19/10	7/7	ND
6	7	81/33		123/95			2155	1930		35/7	108/89	ND		9/6	14/7	ND
7	8	81/39	107/-	97/62	6.8		2026	1700	48/-	46/8	98/76	ND	8/-	15/8	17/2	ND
8	0	78/-														
9	6.5															
10	6.5															
11	6															
12	6															
14		61/38	70/-	48/35	8.5	7.3	1082	944	72/-	73/13	150/131	ND	21/-	28/11	39/34	ND
15	7.5		-/401	143/121	7.4	7.5	1364	1166	54/-		66/58	ND	-/124	20/-	23/22	ND
16	6		88/-	65/65	7.9	7.4	1698	1574	47/-		65/48	ND	18/-		30/21	ND
21	5.5															
22		89/33	-/328	232/127	7.9		1650	1540		38/26	54/40		-/114	36/21	55/41	
23		56/29	70/-	63/57	8.5	7.6	2095	1805		32/15	41/30	ND	5/-	15/11	11/10	ND
24				72/61			2430	2090		27/14	78/27			18/14	59/17	
26	7															
27	9	58/37		50/38	11.3	7.3	1410	1190			47/32	2.8			20/12	ND
28	10			117/94		7.4	910	780			4/3				4/4	

(*) ND = Non Detectable

TABLE C-4

FEBRUARY 1973 OPERATING DATA

	MIXED LIQUOR		PRIMARY STRAINER		SECONDARY STRAINER		AERATION TANK		
Date	Load Factor $\frac{\text{Lbs BOD}}{\text{Lb MLVSS}}$	Wasted Solids Lbs/day	Head in H_2O	Velocity Ft/Min	Head in H_2O	Velocity Ft/Min	Return Flow gpm	Return SS mg/l	Air Flow Lbs/hr
1			13.0	245	0.4	257	6	24	126
2			1.5	3[illegible]	6.0	257	4	40	126
3							5		
4							5		
5			1.5	377	2.75	377	5	43	118
6			9.0	377	2.5	377	6	251	118
7	0.17		0.5	345	3.0	358	3.1	420	152
13		20.2							
14	0.26		8.4	685	9.0	502	3.8	280	82
15			2.9	358	4.5	446	4.2	178	164
16	0.23		3.1	358	6.6	565	3.8	190	146
22			2.9	342	4.8	446	3.8	135	148
23	0.26		2.9	345	6.5	565	3.8	45	147
24			1.3	345	30.0	565	3.8	25	147
27			1.8	342	6.8	565	5.0	26	149
28			15.8	342	29.5	565	3.0	10	119

Primary Strainer: 20 micron fabric, ultrasonic current 4.3-6.1 amps
Secondary Strainer: 10 micron fabric, ultrasonic current 3.7-5.9 amps

TABLE C-5

MARCH 1973 PERFORMANCE DATA

	PRIMARY EFFLUENT						MIXED LIQUOR		PRIMARY STRAINER EFFLUENT				SECONDARY STRAINER EFFLUENT			
Date	Q gpd x 10^3	TOC/SOC mg/l	BOD/COD mg/l	SS/VSS mg/l	NH_3-N mg/l	pH	SS mg/l	VSS mg/l	BOD/COD mg/l	TOC/SOC mg/l	SS/VSS mg/l	NH_3-N mg/l	BOD/COD mg/l	TOC/SOC mg/l	SS/VSS mg/l	NH_3-N mg/l
1	12	49/24	-/216	82/65	8.4	7.7	1680	1460		24/15	22/16		-/64	18/11	14/12	ND (*)
2	15	61/44	95/-	68/57	9.9	7.4	530	450					12/-	19/15	10/8	ND
3	7															
4	6															
5		46/29		51/38			204	158						20/11	24/19	
6				203/201			216	178								
7	7			63/51			332	284							6/4	
8	3			79/66			600	460			111/83					
9	6	91/37		115/80		7.5	915	760		20/17	142/114			64/17	148/111	
10	6															
11	6															
12	8	52/32	59/-	40/34	17.3	7.2	1472	1310		50/11	132/108	ND	7/-	22/13	29/21	ND
13	4	72/33		124/-	8.5	7.3	470	-		58/8	154/-	ND		38/9	62/-	ND
14	8	65/25	87/-	143/113	11.3	7.6	950	810						38/9	100/66	ND
15	8	70/32		80/57		7.3	1255	1085						12/7	12/8	
16	8	54/22		86/68	12.2	7.6	1915	1655		52/8	124/100	1		27/9	63/42	1
17	8															
18	8															
19	3	49/17		79/63	8.8	7.5	2310	1900		28/6	50/35	ND		8/6	3/2	ND
20	7	70/20		133/105	10.7	7.4	2550	2120		11/6	56/12	5		20/6	33/23	ND
21	3	50/20	60/-	59/49	13.8	7.5	2370	2130		42/8	98/77	ND	8/-	13/7	22/19	ND
22	5	46/21	-/153	42/26	9.9	7.6	2420	2080		36/7	76/59	ND	-/45	14/6	19/15	ND
23	9	57/30	95/-	73/55	7.7	7.1	2750	2290		20/5	46/32	ND	13/-	11/6	19/14	ND
24	5															
25	2															
26	15	80/28	-/131	104/98	23.2	7.6	3130	2690		11/6	20/16	1	3/-	8/6	9/4	ND
27	6	104/31		420/310	9.4	7.4	3730	3150		24/5	58/30	1		11/8	13/5	ND
28	6	77/40	85/-	110/56	25.4	7.6	3220	2780		19/17	22/13	ND	13/-	15/6	19/14	ND
29	15	54/19	-/217	100/50	8.5	7.8	3300	2790		24/8	94/66	ND	-/88	15/7	40/26	ND
30	8	75/42	117/-	72/59	11.0	7.4	6240	5400		46/9	89/70	ND	74/-	59/10	140/110	ND
31	8															

(*) ND = Non Detectable

TABLE C-6

MARCH 1973 OPERATING DATA

	MIXED LIQUOR		PRIMARY STRAINER		SECONDARY STRAINER		AERATION TANK		
Date	Load Factor $\frac{\text{Lbs BOD}}{\text{Lb MLVSS}}$	Wasted Solids Lbs/day	Head in H_2O	Velocity Ft/Min	Head in H_2O	Velocity Ft/Min	Return Flow gpm	Return SS mg/l	Air Flow Lbs/hr
1			1.9	350	12.5	750	0		176
2	0.18		4.5	380	17.0	580	5.2	14	132
4			1.9	350	11.0	750	3.8	324	130
12	0.07		2.9	420	6.8	450	3.8	256	135
13			11.4	310	12.8	750	3.8	252	142
14	0.17		11.1	310	0	580	1.7	293	150
16								236	
19			1.4	350	8.8	620	3.8	96	142
20			2.4	380	27.5	380	3.8	124	152
21	0.06		5.4	570	3.2	380	3.8	141	86
22			4.9	500	15.7	760	2.1	114	141
23	0.03		6.4	500	7.1	580	2.1	60	136
26			3.4	360	7.3	570	1.7	19	135
27			3.9	360	9.5	600	3.8	190	139
28	0.04		9.1	350	20.4	650	3.8		132
29			2.9	380	21.5	840	0		160
30	0.07		5.6	380	9.3	720	0		156

Primary Strainer: 20 micron fabric through 3/4/73
40 micron fabric 3/5/73, Ultrasonic current 5.6-6.0 amps

Secondary Strainer: 10 micron fabric, ultrasonic current 3.7-4.3 amps

TABLE C-7

APRIL 1973 PERFORMANCE DATA

	PRIMARY EFFLUENT						MIXED LIQUOR		PRIMARY STRAINER EFFLUENT				SECONDARY STRAINER EFFLUENT			
Date	gpd x 10^3	TOC/SOC mg/l	BOD/COD mg/l	SS/VSS mg/l	NH_3-N mg/l	pH	SS mg/l	VSS mg/l	BOD/COD mg/l	TOC/SOC mg/l	SS/VSS mg/l	NH_3-N mg/l	BOD/COD mg/l	TOC/SOC mg/l	SS/VSS mg/l	NH_3-N mg/l
1	8															
2	8	93/52	137/-	73/61	19.9	7.3	5980	4940		56/5	118/87	ND (*)	3/-	8/2	8/4	ND
3	10	103/54		158/132	10.5	7.2	6140	5220		32/6	67/59	ND		17/6	21/18	ND
4	12	69/39	108/-	85/72	31.0	7.5	6040	5130		27/6	55/45	ND	32/-	32/7	56/47	ND
5	14	67/32	-/263	80/73	9.6	7.4	6440	5510		17/4	27/21	4	-/44	10/4	11/10	ND
6	14	76/50	143/-	83/73	20.0	7.0	6400	5620		13/7	45/44	2	4/-	10/5	12/11	ND
7	14															
8	14															
9	16	54/19	98/-	56/46		7.7	5420	4740		20/7	55/50		7/-	15/9	21/18	
10	20	73/27		110/110	11.0	7.5	5660	4700		13/8	10/5	2		12/8	6/4	2
11	16	81/26	148/-	90/80	14.0	7.8	5750	4670		24/9	34/19	3	10/-	15/8	12/6	3
12	16	65/24	-/163	46/35	8.5	7.5	5900	5020		15/7	21/16	ND	-/29	23/12	21/14	ND
13	14	146/28	-/173	168/160	14.0	7.5	7180	6040		23/12	21/14	ND	4/-	14/10	5/4	ND
14	10															
15	10															
16	14	96/25	188/-	240/195	16.0	7.4				130/110	48/32	11	6/-	22/18	9/8	ND
17	10	76/32		130/110	11.0	7.0	9040	7680		34/20	35/30	ND		45/18	40/32	ND
18	6	67/21	133/-	91/55	14.0	6.7	11360	10240		93/64	76/54	ND	82/-	105/63	80/61	ND
19	10	98/48	-/296	122/108	27.0	7.8	10080	8640		53/25	45/10	ND	-/127	48/26	42/9	ND
20	10															
21	10															
22	10															
23	12	81/23	96/-	113/83	13.0	7.1	9320	7960		19/8	16/10	2	2/-	13/9	7/3	1
24	12	124/24		326/274		7.1	8200	7040		21/8	37/24			13/8	21/15	
25	9	145/55	247/-	144/138		7.0	8320	7680		22/8	18/25		5/-	18/8	15/13	
26	16	92/41	-/311	116/98	8.0	7.6	9480	8000		35/11	39/16	2	-/34	12/12	11/8	ND
27	18	91/51	189/-	214/178		7.6	7990	6870		30/25	43/34		22/-	24/15	44/36	
28	12															
29	8															
30	10	212/19		464/373		7.6	7410	6080		48/12	109/64			16/6	23/17	

(*) ND = Non Detectable

TABLE C-8

APRIL 1973 OPERATING DATA

	MIXED LIQUOR		PRIMARY STRAINER		SECONDARY STRAINER		AERATION TANK		
Date	Load Factor Lbs BOD Lb MLVSS	Wasted Solids Lbs/day	Head in H_2O	Velocity Ft/Min	Head in H_2O	Velocity Ft/Min	Return Flow gpm	Return SS mg/l	Air Flow Lbs/hr
1							3		
2	0.06		2.9	360	7.5	630	3	197	154
3			2.4	360	7.5	630	3		160
4	0.07		2.1	380	10.2	570	3	79	160
5			3.6	380	6.8	570	3	297	156
6	0.09						1	43	
9	0.09		1.9	400	1.4	500	1	52	158
10			2.9	400		720	1	81	158
11	0.13		2.2	400	10.0	680	1		158
12 (*)			3.4	400	7.0	570	2	90	156
13 (*)			2.9	400	7.0	570	3	112	150
14							3		
15							3		
16 (*)	0.31		2.9	380	7.0	560	3	90	149
17 (*)			2.9	380	6.5	560	3	84	170
18	0.07	16	1.8	460	5.0	470	3	41	300
19		65	2.9	350	4.5	460	3	64	152
20							3		
21							3		
22							3		
23	0.03	40	3.2	380	4.5	470	3	66	172
24		35	3.0	380	4.5	470	3	78	170
25	0.07		3.1	380	4.0	470	3	52	170
26		20	3.5	380	4.8	470	3	103	170
27	0.08	29	5.2	570	11.6	380	3	30	175
28							3		
29							3		
30		10	3.4	570	4.8	380	3	315	175

(*) Dext molasses added (not recorded in influent sample)

Primary Strainer: 10 micron fabric, ultrasonic current 5.9-6.9 amps
Secondary Strainer: 5 micron fabric, ultrasonic current 3.3-4.2 amps